MEMOIRS

OF THE

LITERARY

AND

PHILOSOPHICAL SOCIETY

OF

MANCHESTER.

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ERRATA.

Page	155,	line	23,	for "found" read "formed"
..	179,	..	3,	.. "Canal" read "Cannel"
..	190,	..	25,	after "casts" insert "of"
..	203,	..	23,	for "No. 4" read "No. 1"
..	207,	..	11,	.. "No. 1" read "No. 4"
..	347,	..	7,	.. "subtlety" read "subtilty"
..	347,	..	14,	.. "takes" read "take"

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LITERARY AND PHILOSOPHICAL SOCIETY

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MANCHESTER.

I.—*On some of the Microscopical Objects found in the Mud of the Levant, and other Deposits; with Remarks on the mode of formation of Calcareous and Infusorial Siliceous Rocks.* By W. C. Williamson, Esq.

Communicated by J. P. Joule, Esq. (Read November 4, 1845.)*

Having received from my two friends, Mr. Wm. Reckitt, of Boston, and Mr. Sidebotham, of Manchester, specimens of the friable calcareous deposit which is now accumulating under the waters of the Levant,† I have resolved, after a

* Some additional matter has been incorporated since the Paper was read.

† The term Levant, "is applied not only to the shores, but the seas, over which the sun rises to the morning-ward of Malta." The Crescent and the Cross, by Elias Warburton, Esq. Vol. ii. p. 1.

careful examination of them under the microscope, to offer the results of my observations to the Society, believing that the subject will be interesting to the members on two accounts. In the first place, because the deposit furnishes an admirable illustration of the agencies, by which many of the more ancient calcareous rocks have been formed; and in the second, because the microscopic organisms with which it abounds, exhibit beautiful examples of some of those lower tribes of plants and animals, which are now attracting general attention, but many of which have not yet been brought before this society.

Various speculations have been advanced to account for the origin of cretaceous and limestone strata. Of these, time will not allow me to dwell upon more than the two or three which have been the most popular.

The first is the hypothesis, which supposed, that calcareous rocks have been formed by the accumulation of the comminuted portions of shells and corals, previously broken up by the mechanical movements of the ocean; a view, which was entertained by Linnæus in 1745, and again by Buffon in 1749, and which has been more recently

revived by Mr. M'Culloch,* though in a somewhat untenable form. This hypothesis was considered to be open to several objections,—especially when applied to such strata as the Chalk. One was, that such an accumulation of broken shells and corals, could scarcely be conceived to consist of particles so minute and uniform as those of the Chalk. Another, that any mechanical action, as that of water, equal to the production of such a degree of comminution, would also have destroyed the sharp outlines of the imbedded fossils. The same difficulties existed with reference to many of the older limestones, but less so to some of the coarse deposits of the Oolitic Era.

Analogous to this was the supposition that many limestone strata had been vast coral reefs, enclosing and alternating with calcareous sediments, produced by the abrasion of shells and corals by the waves.† Though partly applicable to some of the beds of the Coralline Oolite of Yorkshire, yet this hypothesis when applied to

* M'Culloch's System of Geology. Vol. i. p. 219.

† Lyell's Elements of Geology. p. 220. Many illustrative facts are also recorded in the third edition of his Principles of Geology. Vol. iii. p. 234, et seq.

limestones on an extended scale, was open to the same objections as the preceding one.

These explanations not being considered satisfactory, another view was propounded, and received by many as sufficient to account for most of the phenomena presented by calcareous rocks. It was supposed that the waters of the ocean contained large quantities of lime in solution, and that in the deeper seas, where undisturbed by local currents produced along the coasts, a slow chemical decomposition took place, causing the precipitation of an insoluble carbonate of lime.* To account for the existence of lime in the sea, submarine volcanoes and volcanic springs were had recourse to; it being supposed, not without reason, that such springs did from time to time discharge large quantities of calcareous matter into the ocean.†

Faint glimpses of another hypothesis had been obtained by a few authors. Early in the eighteenth century, Soldani had collected, from less than an ounce and a half of stone from the hills of

* Encyclopædia Metropolitana. Article, Geology. pp. 544 and 656.

† Lyell's Principles of Geology. Vol. iii. p. 240.

Casciana, in Tuscany, 10,454 microscopic chambered shells, and had observed that the rest of the stone was composed of fragments of shells, of minute spines of Echini, and of a sparry calcareous matter. He was also aware that analogous microscopic organisms existed in vast abundance in the waters of the Mediterranean.* Lamarck had subsequently observed the abundance of minute, but perfect Foraminifera in the strata in the neighbourhood of Paris, and remarked "that the remains of such minute animals have added much more to the mass of materials which compose the crust of the globe, than the bones of hippopotami, elephants, and whales."† The Abbé Alberto Fortis, Targioni Tozzetti, and other observers, had likewise noticed the existence of strata composed entirely of accumulated Nummulites.‡

Such was the imperfect state of things when, in 1835, Professor Ehrenberg startled the scientific world by the announcement, that there were in existence rocks composed wholly and entirely of the fossil remains of animals so minute, that

* Lyell's Principles of Geology. Vol. i. p. 77.

† Buckland's Bridgewater Treatise. p. 388.

‡ Parkinson's Organic Remains. pp. 156 to 158.

40,000,000 would only occupy the space of a cubic inch; and in 1838 he stated to the Royal Academy of Sciences of Berlin, that the common white Chalk, in many localities, contained vast numbers of siliceous Infusoria, of five or six species, as well as Polythalamia,—microscopic chambered shells, then generally considered to be minute Cephalopoda. In 1837 our countryman, Mr. Lonsdale, found that the English Chalk contained many of these microscopic Polythalamia.* Similar forms were also detected by the above observers, and by the Rev. J. B. Reade, in flints and analogous siliceous structures.† These facts led many to the conclusion, that Chalk and Chalk flints, if not all calcareous deposits, had been formed, not so much by the broken atoms of the larger organisms, as by the accumulated remains of siliceous Infusoria and calcareous Foraminifera. This view seems to be held by Ehrenberg, who, to account for the presence of what appear to be inorganic atoms, remarks, that "The minute inorganic calcareous particles, produced by the disintegration of the microscopic organisms, are united by a peculiar crystalloid process, which

* Lyell's Principles of Geology, p. 56.

† Annals of Natural History. Vol. xi. p. 194.

may be compared to crystallization, but is of a coarser nature, and essentially different from it."*

Thus we are manifestly approximating to the early conceptions of Linnæus and Buffon, who, if the above views are correct, were not far in error in the general principle which they advocated, viz., the organic origin of limestone rocks,—though they were completely in the dark as to the facts by which the correctness of their hypothesis was to be ultimately tested and proved.

In most geological questions, we are only safe in our generalizations, so long as we test our explanation of the phenomena presented in the crust of the globe, by the effects of active agencies now operating upon its surface. Fuschel laid the foundation of a glorious truth when he declared, that "the earth has always presented phenomena similar to those of the present day."† It is a vital error to regard the world as having been the theatre of agencies which have long since ceased to act. Overwhelmed by the evidences of mighty forces and indefinite periods, we are in danger of forgetting

* Observations on the Organic Composition of Chalk and Chalk Marl.—Mag. Natural History, 1841, p. 305.

† Delabeches's Geol. Manual, p. 193.

that nature is, on the whole, unchanged in the general choice of her instruments, as well as of the laws which regulate their operations; and that, consequently, if we would hope to penetrate the mysterious labyrinth in which she has left many of her ancient secrets concealed, we must commence with the existing exhibitions of nature at work, and trace backward the winding paths by which she has advanced. She is still labouring as of old; and Mr. Lyell has done geologists a noble service in impressing on their minds the extent and power of the forces she has still at her command. By thus diligently enquiring what she is doing, and can do, we may arrive at a comprehension of what she has done, and of the way in which it has been accomplished.

These views apply especially to the *quæstio vexata* of the origin of calcareous strata, many of which have undergone such chemical changes since they were deposited, as have rendered the records of their early history obscure. An extensive metamorphism has changed their appearance, —characters, once clear and legible, are now like those of a time-worn manuscript, difficult to decipher. But in recent calcareous deposits, like that of the Levant, we are able to investigate a portion

of this problem under advantageous circumstances. The sedimentary accumulation is now going on. The organisms which constitute it, are unaltered in their structure; and indeed, many of them still contain green animal matter, shewing them to have been living when they were collected. They have been subjected to none of the changes produced by long-continued chemical action, or mechanical pressure; and, consequently, in this example we may form some estimate of how much is owing respectively to organic and inorganic causes.

It has long been known to geologists that in both the Adriatic and the Mediterranean a modern calcareous stratum is in process of formation. On examining several specimens of this sediment, brought me from the Adriatic side of the Levant, under a magnifier having a power of 250 diameters, I found that what, to the unassisted eye, appeared to be a fine powder, mixed with fragments of broken shells, is mainly, if not entirely, an accumulation of organic atoms, of which the greater number are minute and perfect organisms, varying from 1-20th to 1-2000th of an inch in diameter. These consist chiefly of Foraminifera, micro-

scopic Corallines, siliceous Infusoria, spicula of Sponges, and detached frustules, belonging to the interesting group of Diatomaceæ. Another part was composed of the small comminuted fragments of Echinoderms, and some of the larger Molluscs, the latter consisting chiefly of detached and broken prisms of carbonate of lime, such as a very small geological change would convert into what would appear inorganic semi-crystalline atoms. Of truly inorganic fragments, excepting a few sand grains I have seen few or no traces. There are many which I once conceived to be such, but one after another, I have been able to identify them all, and am now led to believe that the whole deposit owes its existence to the steady and continued operation of vital causes. It is not intended to assert, with M'Culloch, that lime is an organic product, but that, so far as portions of the Levant mud are concerned, living organizations have been the sole instruments by which lime and silica have been separated from the water of the seas, and converted into an insoluble form, their constant accumulation causing the existence of a calcareous sediment, which only requires a sufficient length of time, without the interference of any great physical disturbing causes, to produce strata of indefinite thickness.

I will now direct the attention of the Society to the character, and more remarkable forms of these interesting structures.

In the lowest departments of the animal and vegetable worlds, there exist several groups of organisms of doubtful affinities, which have consequently been claimed alike by the botanist and the zoologist. Amongst the most interesting of these are the Diatomaceæ and the Desmideæ. Professor Ehrenberg has figured many of them in his large work on living Infusoria, as animals; for, although he occasionally asks the question, "an animale, an vegetabile?" it is easy to see to which side he inclines. Mr. Dalrymple has also advocated the same view with reference to some of the genera. On the other hand, Kutzing, Agardh, Meneghini, Berkley, Greville, Ralfs, and a host of botanists, have held the opposite opinion, and viewed them as early forms of vegetable life. With reference to the Desmideæ*

* Though the Desmideæ have less connexion with the object of this paper than the Diatomaceæ, the question of their nature is not altogether alien. Some of the beautiful stellate and hirsute spores of Staurastrum, and allied genera, bear so close a resemblance to the fossil Xanthidia that some naturalists are convinced of their identity. I possess spores

there is little doubt but that the botanists are right. The advocates of their animal nature have laid great stress upon their (supposed) powers of locomotion; the admission of indigo into their interior; their increase by self-division; the contractility of their lining membrane on the application of certain reagents; and on the assumed absence of starch from their interior.

None of these reasons appear sufficient to establish the point, even did they all exist. Locomotion is certainly not peculiar to the animal kingdom: the spores of many undoubted Confervæ commence their active and restless movements before they leave the cells of the parent plant. After they escape, Mr. Hassal observes, "they fall into the water, through which they speedily begin to move hither and thither; now progressing in a straight line, with the rostra in advance—now wheeling round and pursuing

of Staurastrum mucronatum, collected by my enthusiastic friend Mr. Ralfs, which cannot possibly be distinguished, so far as form is concerned, from many specimens of Xanthidium ramosum, so common in chalk flints. Notwithstanding this, however, my present conviction is, that the Xanthidia will prove to be spores or gemmules of some of the lower animals,—Polypifera or Porifera.

a different course; now letting their rostra drop and oscillating upon them, like balloons ere the strings are cut, or like tops, their centripetal force being nearly expended; now altogether stopping, and anon resuming their curious and eccentric motions. Truly wonderful is the velocity with which these microscopic objects progress, their relative speed far surpassing that of the swiftest race-horse; after a time, however, the motion becomes much retarded, and at length the zoospores then lie as though dead. Not so, however. They have merely lost the power of locomotion. The vital principle is still active within them, and they are seen to expand, to become partitioned, and if the species be of an attached kind, each zoospore will emit from its transparent extremity, two or more radicles, whereby it becomes finally and for ever fixed."* The admission of indigo into the interior of the Desmideæ, is a very unsatisfactory test, even had it been observed to succeed in all cases, which it has not. The increase by spontaneous division is now shown to be exhibited by many of the true Confervæ, of whose vegetability there can be no doubt. Indeed, it is probable that something very

* Hassal's History of British Freshwater Confervæ. Vol. i. page 11.

analogous to division is the basis of the increase of most cell structures, animal as well as vegetable. The contraction of the lining membrane is also observed, according to Mr. Hassal, in many Confervæ. The assumed absence of starch from their interior is shewn by Meyen, Ralfs, and Jenner, to be an error.

On the other hand, there are certain peculiarities of a positive kind which identify them with plants. Of these I will only cite that of conjugation, which connects them by the closest possible analogy, with a large number of true Algæ.

The real nature of the allied group of the Diatomaceæ is a question less easily disposed of. They are objects more or less filamentous, the filaments being divided into joints or frustules, composed of pure transparent silex, and containing in their interior brown colouring matter, and a number of vertical siliceous plates, the visible edges of which often give to the surface of the frustules the most elaborate markings. These joints exhibit a constant tendency towards a partial separation, cohering only by one of their angles. Their reproduction appears analogous in many cases to that of the Desmidiaceæ, being probably

by germs or spores, or, as appears to be the case in many species, by the formation of two new siliceous cells, in the interior of the old one, each cell thus becoming the germ of a new and self-increasing organism. There are many reasons for referring these curious and elegant creatures also to the vegetable world; but on the other hand, many points of their history bring them so near to the Coscinodisci, and other supposed siliceous Infusoria, that it appears almost impossible to come to a definite conclusion on the subject.

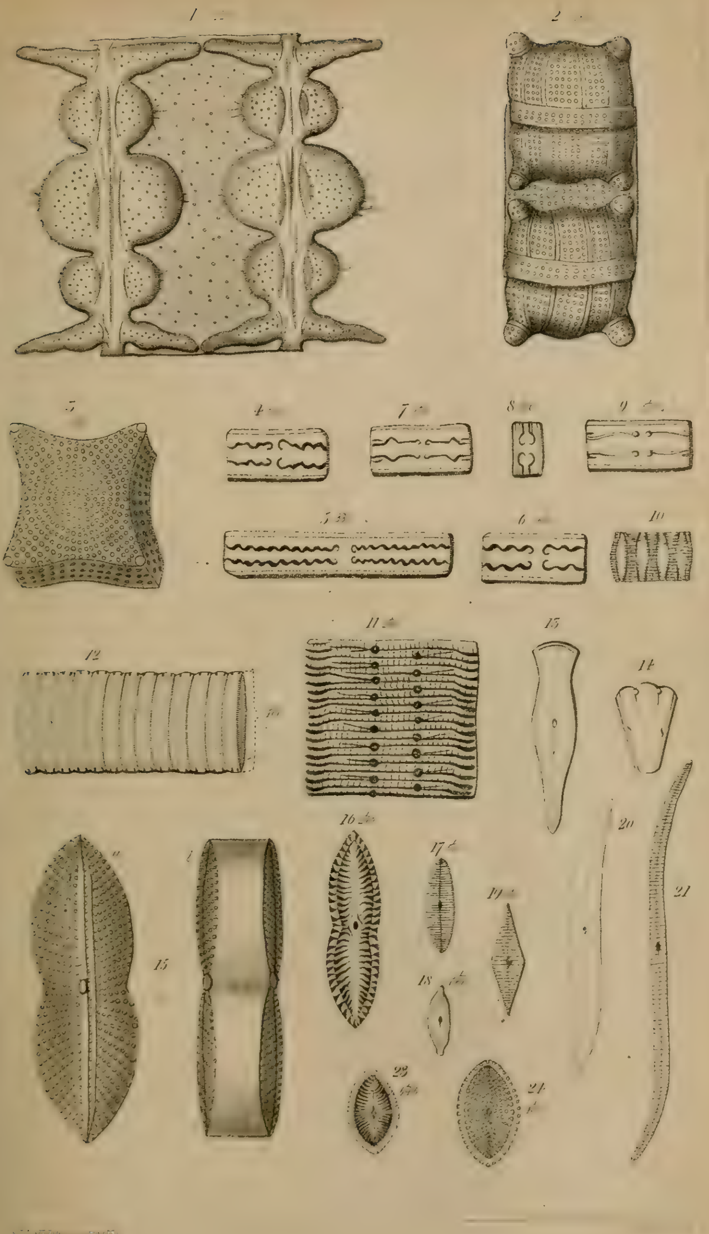
I have dwelt the longer on these families because of their growing importance to geologists. Most modern geological works contain some allusion to them under the terms Gallionellæ, Baccillariæ, &c.*; but very few doubt for a moment their animal character. The extensive discovery of their siliceous cases amongst tertiary strata, especially by Professors Ehrenberg, Bailey, and Rogers, has given them an important position amongst the organic remains of a former world; and, consequently, it is desirable to bear in mind, in our generalizations, that the question of their real nature is yet *sub judice*.

* Lyell's Elements, p. 52.—Dr. Bailey's valuable Papers in Silliman's American Journal.

Many highly interesting examples of this group occur in the Levant Deposit. The most striking is the *Denticella tridens*, *Ehr.*—the Zygoceros Tuomeyi of Bailey. (fig. 1.) The figure represents two of the frustules, many of which have probably been joined together, forming an elongated filament. The same species has been found by Dr. Bailey in the siliceous infusorial marls of Piscatoway and Petersburgh, North America.

Biddulphia pulchella (fig. 2.) is another beautiful form belonging to the same group. Two frustules are also represented. It is found on our own coasts. Dr. Ehrenberg has obtained it from what he considered to be the chalk marls of Greece, and also in a recent state in the Baltic, the North Sea, and from the coast of Cuba; Dr. Bailey has detected it at Rockaway, Long Island; and it is contained in a slide of curious objects from one of the Phillipine Islands, for which I am indebted to the same indefatigable observer:—an interesting illustration of the cosmopolite character of some of these organisms.

Amphitetras (fig. 3.) is an analogous genus, of which the end of one frustule is exhibited. One species, the A. antediluviana, occurs on the British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coasts, but differs from the present form in having its lateral surfaces less concave. It may, however, only be a variety; as many of the Diatomaceæ exhibit considerable variations of form in the same species.

Grammatophora presents at least two species. *G. Africana, Ehr.* (figs. 4.6.—fig. 8. is probably a small variety of the same—*), and G. tæniæformis (fig. 7, and probably fig. 9.) The former of these species occurs on our coasts. I have received it from Mr. Ralfs, who collected it at Ilfracombe; and I have met with it rather abundantly, along with G. tæniæformis, in the stomachs of crabs from the west coast of Scotland. It is one of the most beautiful of this interesting group, and when occurring in long, zigzag chains, the partially separated frustules cohering by the angles, it constitutes an exquisite microscopic

* Mr. Ralfs writes to me, "Kutzing names my Striatella tæniæformis, var γ serpentina, Grammatophora serpentina, with the following synonyms:—Stri. tæniæformis γ serpentina, Ralfs. Grammatophora Africana, Ehr.? so that, probably, it is Ehrenberg's species." Under Grammatophora marina, Kutzing has the following synonyms:—Conf. tæniæformis E. B. Diat. marinum Lyngb. Diat. tæniæformæ, marinum and Lyngbyei, Ag.—Bacillaria Cleopatra and Grammatophora Oceanica, Ehr.

object. I have also seen it in the guano from Ichaboe.

Fig. 5 may be only an elongated variety of Grammatophora Africana. I have received it from Dr. Bailey amongst some objects obtained at Smyrna, where it occurs along with the true G. Africana. I have never seen it on our own coasts, though G. Africana is not uncommon; hence it may possibly be distinct.

Striatella. (fig. 11.) This is apparently a slight variety of the S. arcuata found on our own coasts.

Fragillaria. (fig. 12.) Long chains of frustules occasionally occur. They are analogous to some of the fossil forms called Bacillariæ. The genus is met with in both fresh and salt water.

Gomphonema. (figs. 13, 14.) This is also a marine as well as a fluviatile genus, in which the frustules are generally supported on a long and flexible stem or pedicle. I have observed two species, both different from those which occur on our own coasts. Fig. 13 may possibly be G. geminatum, which it closely resembles. It is a

freshwater species; but Mr. Ralfs kindly informs us that he has occasionally found it brought down by the rivers into marine marshes.

Arranged along with the Diatomacæe, by many authors, are the singular group of Naviculaceæ, small siliceous boat-like bodies, whose affinities are even yet more doubtful than those organisms already noticed, containing a peculiar green internal organization; not forming chains like most of the preceding genera, but each being independent; possessing great powers of locomotion; manifesting all the phenomena of fissiparous generation, and exhibiting, when treated with iodine, well-marked traces of the existence of the vegetable product starch; connected with the preceding group by the genus Cocconema, in which, as in Gomphonema, the siliceous frustules contain a granular endochrome, and are supported on long flexible pedicles; and yet, when detached, the frustules being distinguishable by any known character from true Navicula! Altogether, we are involved in a labyrinth of difficulties, from which we cannot easily extricate ourselves.

Ehrenberg believes that he has observed in

several forms retractile pseudopodia,—organs of progression projected through pores in the siliceous cases. If he be correct, this would seem to identify them with the animal kingdom; but neither have I, nor any of the microscopists with whom I have come in contact, been successful in our search for these pseudopodia.

A great variety of forms belonging to this interesting group occur in the Levant deposits. From these I have selected some of the most remarkable. Figs. 15 to 21 represent various examples of the genus Navicula. Fig. 15 is a beautiful and not uncommon species,—*a* exhibits the anterior and *b* the lateral aspect. Fig. 20 is apparently Ehrenberg's Navicula sigma.

Fig. 22 is an exquisite species of Surirella, allied to S. elegans, *a* representing the front, and *b* one extremity of the shell. Figs. 23 and 24 are two species of Cocconeis, a genus of parasitic forms which occur in the greatest abundance on the English coasts, many of the smaller Algæ being covered with them in the most incredible profusion. Their power of fixing themselves to foreign substances, appears to indicate the existence of something allied to the pseudopodia of Ehrenberg.

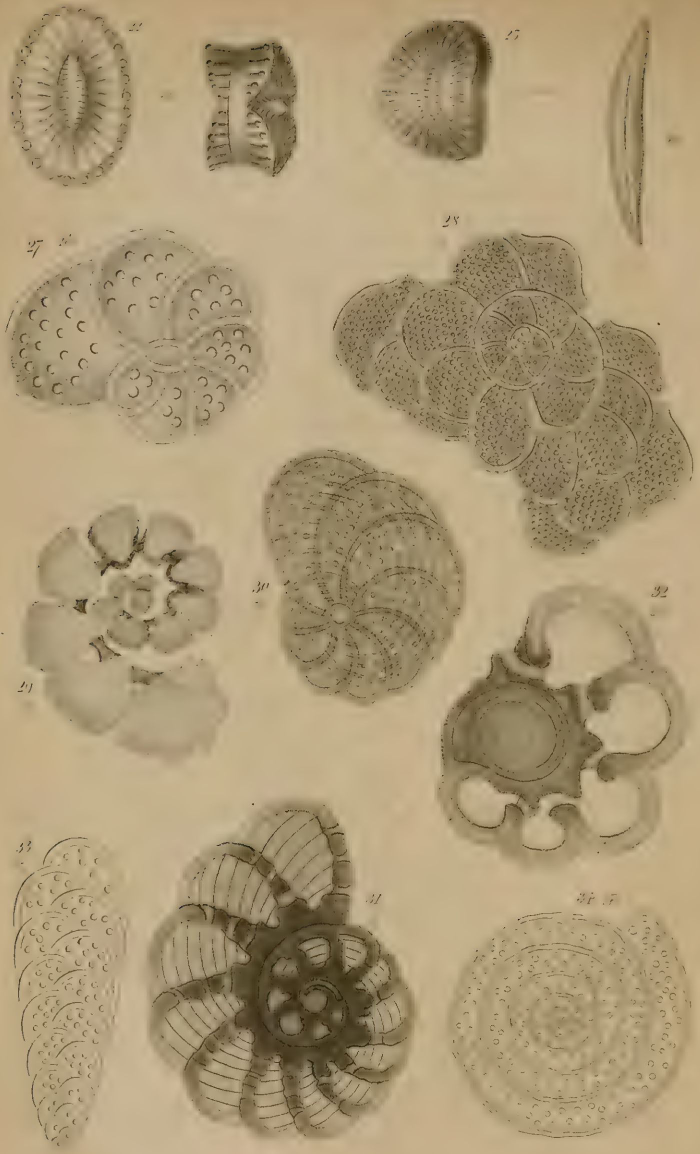
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Fig. 25* is a species of Cocconema, separated from its pedicle, which latter character alone seems to distinguish this curious genus from the Naviculæ.

The objects to which I would next direct attention also belong to the disputed domain which appears to link the animal with the vegetable kingdom. They are the spicula of sponges. It has long been known that some sponges have their elastic network strengthened by siliceous and calcareous spicula; but the number of forms with which naturalists were acquainted was very limited, and indeed mainly referable to two types, the acicular and the tri-radiate, the former being long believed to represent the siliceous, and the latter the calcareous structures. Within the last few years, however, the labours of Mr. Bowerbank and others have led to the discovery of many varieties, alike peculiar and beautiful. Several of these occur in the Levant mud, as might have been expected from the known abundance of sponges in the Mediterranean and neighbouring seas.

* The number is accidentally omitted from the figure in the upper corner of Plate II.

Whether the sponge is an animal or a vegetable is as yet an undecided question. Dr. Johnston holds the latter opinion; whilst Dr. Grant and others, judging from the anomalous movements they communicate to surrounding fluids, so often spoken of as a circulation,* and from the developement and motion of their ciliated germs, contend for their animal nature. The latter, however, have been already shown to be phenomena often observed in the lower departments of the vegetable kingdom. Mr. Bowerbank, after pointing out the existence of spicula in some of the Corallidæ (Anthopora) so closely resembling those of many of the Halichondriæ (fig. 46) as not to be distinguished from them, argues from this and some other analogous facts in favour of their

* This peculiar movement is admitted by all to be a difficulty in the way of their being regarded as vegetables. It is much to be desired that the term "circulation" should cease to be applied to it, as the expression gives an erroneous idea of the nature of the movement, and most probably of its object also; for to consider sponges as possessing a true circulation and capillary vessels, as is done by some microscopic observers, is to set at defiance all the fundamental truths of physiology—truths not to be assailed except after long observation, and on the clearest possible evidence.

animality.* Mr. Hogg, in his investigation on the action of light as affecting the colour of the river sponge, *Spongilla fluviatilis*,† has advanced good arguments in favour of its being a plant, a conclusion in which most naturalists are now agreed. Dr. Bailey has pointed out the existence of siliceous spicula in unquestionably fresh-water deposits in the state of Maine, U. S., so analogous to those of some marine sponges as to be almost identical;‡ yet they are doubtless those of a fresh-water species. This is supported by Struve's analysis of the Spongilla, in which he found, that the ashes left after combustion contained 94.66 per cent of silica.§ These facts indicate a close affinity between the marine and fresh-water forms, and, consequently, increase the probability that the former are more closely allied to the vegetable than to the animal world. On the other hand, the existence of analogous siliceous spicula in Cliona and Anthopora and calcareous ones in the tissues

* Mr. Bowerbank on the Organic Tissues in the Bony Structure of the Corallidæ. Phil. Trans. Royal Society. 1842. Part I, p. 219.

† Paper read to the Royal Society, June 21, 1838.

‡ Silliman's Journal. Vol. xlvi. p. 307.

§ Records of General Science, 1836. Vol. iii. p. 157.

of many of the Eolidæ,* constitute important links connecting them with the animal kingdom. By what mysterious process the simple textures of the sponges have the power of throwing into such exquisitely beautiful forms the silica obtained from the waters of the ocean, it is impossible to say. The manner in which each species preserves its own, in many instances peculiar, form, indicates that there is some apparatus for effecting the object which has as yet escaped detection. In a number of instances, a species may be identified by its elaborately marked spicula; and in others, where one general type prevails, as in the case of the acicular spiculum amongst the Halichondriæ, the different species often present well marked peculiarities of size and form. Sponge spicula are not equally numerous in all the specimens of Levant sediment that I have examined. In some they are very abundant —in others they are comparatively rare. This was to be expected, as any local causes influencing the growth of living sponges would also affect the distribution of their spicula.

The most common form is the calcareous tri-

* See Alder and Hancock's Monograph on the British Nudibranchiate Mollusca.

radiate (fig. 45.) It occurs in many living species. The siliceous acicular spiculum is also abundant, sometimes with one end thickened like the head of a pin (fig. 47) a form which I have found in the British Halichondria sulphurea (*Bean's MSS*); and which also exists in Dr. Grant's sponge-like Zoophyte, Cliona celata;* at others pointed at each extremity (fig. 46). The latter is the most common siliceous form, and has been found by Mr. Bowerbank in many of the keratose sponges, from which they were believed to be absent, and which were, consequently, made into a separate group. Fig. 46 is not only the common form amongst the Halichondriæ, but has been found by Mr. Bowerbank in Anthopora—one of the Corallidæ.†

Two forms of spicula occur, which, probably, belong to some species of Tetheia. In the fibro-fleshy texture of this sponge there are bundles of spicula which radiate from the centre to the

* Found filling the holes in oyster-shells on the sea coast, near Preston Pans.—Johnston's History of British Zoophytes, p. 305.

† On the Organic Tissues in the Bony Structure of the Corallidæ.—See page 22.

circumference, some of them passing through the thick skin or rind. In the latter are bundles of shorter spicula, and in the interstices between these are sparingly scattered minute stellate siliceous bodies of great beauty, resembling in form the bossed iron balls hung by a chain to the war club used in the early ages. Examples of at least two species (figs. 40, 41) occur in some specimens of the Levant mud, one of them (fig. 40) being rather abundant. Analogous forms have been found by Dr. Bailey in the siliceous Infusorial deposits of Bermuda and Pittsburg. Stellate spicula occur in some species of the genus Grantia and in Mr. Bowerbank's new sponge Pachymatisma Johnstoniana.

I have also found a considerable number of small siliceous balls, which belong to some species of Geodia.* In this, as in Tetheia, we find long radiating spicula, but with the external extremity often divided into three recurved

* Dr. Johnson refers to the Cydonium Mulleri of Fleming, under the head Geodia Zetlandica, including it among the Sponges.—Hist. of British Sponges, p. 195; and again in his History of British Zoophytes, speaking of it as one of the Alcyonidæ. Are these distinct objects?

points, like grappling irons. The skin, or outer crust, is dry, and consists of an aggregation of small siliceous globules, cemented together by an organic mucus, so as to form a solid pavement. Each globule, both in the living species and in those from the Levant, is delicately reticulated. Fig. 42 represents one of the round spicula, and Fig. 43 is probably one of the radiating ones from the same sponge. Fig. 48 represents a form in which the surface is armed with symmetrical rings of minute points. I have observed it in sponges from our English coast, from the Mediterranean and West Indian Seas, and also along with other organisms in the Ichaboe guano. I have occasionally seen an analogous muricated form in which the small points were dispersed irregularly, instead of being arranged in transverse rings.

Fig. 49 is a portion of a very large calcareous spiculum in which the surface is covered with irregularly arranged projections, or flattened papillæ, which preserve, however, a little tendency to a spiral arrangement. I have seen forms somewhat similar in sand from the West Indies. I suspect they belong to some of the Eolidæ so beautifully illustrated by Messrs. Alder and

Hancock, in the work now publishing by the Ray Society.*

Foraminifera.—The most abundant as well as the most striking organisms belonging to the Levant deposit are the Foraminifera, or Polythalamia;—interesting from their individual peculiarities, and important from their geological relations.

Zoologists have long been acquainted with the existence of recent and fossil forms of microscopic chambered shells from almost every European country. Stobæus had arranged the Nummulites amongst the corals,† thus anticipating later discoveries. In 1732 Breyn pointed out the resemblance between many of the forms and the recent Nautilus, which view was also adopted by Gesner. In the same century Soldani had minutely investigated those of the Mediterranean, treading in the steps of Plancus and others who had led the way;‡ and between the years 1789 and 1799 he published his large work on the subject.

* See Goniodoris nodosa—Table 18, fig. 11, and Polycera ocellata—Table 23, fig. 8. Monograph on the British Nudibranchiate Mollusca.

† In Opusculis.

‡ Annales des Sciences Naturelles. 1826. Vol. vii., p. 102.

In 1784 Walker examined those of our own coast —a labour in which he was followed by Montagu, in 1803 and 1808, whilst Fichtel and Moll recorded many additional recent forms ; and subsequently Lamarck especially studied the fossil species of the Paris basin. M. Dessalines d'Orbigny was the first to reduce the study of these curious organisms to its present form, and the result of his labours, published in 1826,* has constituted the basis of all modern classification of the various species. All the above naturalists, with the exception of Montagu and Stobæus, have referred these chambered structures to the Cephalopoda, arranging them with the Nautilus and the Cuttlefish. Though Montagu held the same view, with reference to most of the species, he pointed out that Troncatulina tuberculata (Nautilus lobatulus, Walker) was found parasitic on Fuci, and being aware that the Nautili are never sessile, he decided that it could not be arranged along with the Cephalopoda. He fell, however, into another error, and placed it, as well as the Miliolæ, amongst the Serpulæ.† Pallas also, speaks

* Tableau Méthodique de la classe des Céphalapodes, Annales des Sciences Naturelles. Vol. vii., p. 96.

† Supplement to the Testacea Britannica, p. 160.

of the fossil Fusulinæ of the limestone of the Volga, as "*small madreporites*," resembling graïns of wheat,* though he was probably unacquainted with their affinity to what were then generally believed to be Nautili, and thus he forestalled the discoveries of a later age, only by accident.

M. Dessalines D'Orbigny, especially, adopted the view that the Foraminifera were Nautili, (though he pointed out the Zoophytic character of the animals of the genus Lagena, erroneously separating them from the Polythalamia,) and produced a general classification of the Cephalopoda, in which he comprehended these minute creatures. He ascribed to them an external animal, bearing the form of a Sepia, the shell itself being considered as an internal bone. M. Dujardin, on the other hand, denied that these animals possessed any organic structure, but considered that they consisted only of an animated slime, capable of extension, encased by an indurated external shell, and, regarding them as Infusoria, associated them with the pseudopodian Amoeba.

* Murchison's Geol. of Russia in Europe. Vol. i., p. 87.

A new light was soon to illumine the subject. In 1823 Dr. Ehrenberg visited the Red Sea, along with his friend, Dr. Hemprich, for the purpose of investigating its corals. He soon became doubtful of the Cephalopodous character of the Foraminifera. The rest I will give in his own words. After careful investigations he says —" The result proved that the disk-like shell (Sorites Orbiculus, Ehr. Nummulina Orbicula D'Orbigny) was a polypary, often composed of more than one hundred single animalcules, the cells of which quite resemble those of a Flustra, the animal putting forth and retracting from six to eight tentacula; and I even discovered in the interior of the single cells well-preserved siliceous Infusoria, the last food taken by the animal; and in some of them, also, small globular bodies, which, without much constraint, may be considered as eggs. Though I had at an early period observed that the disk was composed of many cells, yet I could not perceive an opening to them; but the discovery of Infusoria in their interior led me to consider by what means they could have been introduced. Reflection reminded me that I had often seen coral animals, which in their expanded state exhibited many large bodies

with tentacula and a large mouth, yet when contracted left scarcely a trace of the openings through which they were protruded from the common polypary. As such I had remembered Pennatula, Lobularia, Alcyonium, and similar forms, in which I had frequently observed that in the skin of the animal existed calcareous particles, which, on the contraction of the skin, so completely closed the opening as to render it no longer perceptible. Renewed examination of the closed surfaces of the cells of Nautilus Orbiculus (Forskal) showed me that in them also dendritic calcareous particles exist, the close approximation of which closes the cell—so that the cover of the cell is in fact the dried up skin of the animal. I now made an experiment in proof by dissolving the small cell in muriatic acid, in order to obtain the animal body in a free state. I obtained as many animalcular bodies as there were cells, connected together by band-like processes, and in the interior of many of them were well preserved siliceous Infusoria. I then treated in the same manner Flustra pilosa and F. membranacea of the Baltic, and found in their interior also, siliceous infusoria."*

* Phil. Mag. Vol. xviii. p. 446.

These views, which first dawned upon the mind of Ehrenberg, in 1823, were fully confirmed in 1839, when he completely established the point that these little animals were not to be grouped with the Cephalopoda, but with the Bryozoa or Moss-corals. He has since examined, whilst in a living state, similar animals discovered in the Baltic at Cuxhaven, and elucidated their history still further. He found that in many cases, the foremost or largest cell, and in some cases the two or three following ones, were filled with transparent parts only, but that in general, from the second cell, all the hinder ones were filled with two differently coloured organs,—what he considered to be the thick alimentary canal, and the granular masses, which he suggested may be ovaries. He also found that they had the power of protruding from the foramina in the skin pseudopodia or extensile tentacula, evidently resembling the contractile fringes of Flustra and some minute Gasteropods. He saw great bundles of filaments arbitrarily ramifying, and though not actually, yet apparently confluent, frequently projecting from the surface, but especially from the umbilical region, where he observes there are perhaps distinct and larger contractile apertures.

Some of the genera, instead of having but *one* series of necks or processes connecting the soft animal contents of the various cells together, have several, which also communicate with the exterior by means of a corresponding number of foramina in front of the last cell, some in the centre, some in the circumference. Alcide d'Orbigny was well acquainted with this fact, and it is surprising that it did not lead him to see the error of regarding these animals as Nautili. He was also acquainted with the pseudopodia, as he says, "L'animal fait sortir des filamens non seulement par les ouvertures du dessus de la dernière loge, mais encore par les pores des côtés des dernières loges."* He still, however, regarded these creatures as possessing an exsertile head, with a plumose feeling and prehensile apparatus, as is the case with the larger Cephalopoda.

In addition to the distinctions already noticed between the Foraminifera and the Nautili, especially that of the soft animal filling every cell in the former, whilst in the latter it merely occupies the terminal one, there are two other marked characters, which separate the Polythalamia from the Cephalapoda. One is, that while the septa

* Voyage dans l'Amerique Meridionale. Tome 5ieme, p. 29.

of the latter are always *concave* anteriorly, in the former they are always *convex*. The other is that, whilst in the Nautilus the tube or calcareous part of the siphuncle, always projects *backwards* from each septum, in Foraminifera the reverse always holds good, two distinctions which are of essential importance in deciding upon their affinities.* Owing to the observant genius and skill of Ehrenberg, the opinion that these curious organisms are Bryozoa or Moss corals may now be considered as established beyond all dispute. They are thus brought down from their position amongst the highest and most perfectly developed mollusks to rank amongst the lowest forms of animal life.

There are one or two points connected with their history which I have not found noticed by any of the observers who have written on the subject, and to which I will presently direct attention. The Levant mud contains a great variety of these interesting organisms; indeed, in the time of Soldani (1730), both the Adriatic and the Mediterranean were celebrated for their riches in this department. I have accompanied

* In the genus Endosolenia, Ehr. we have an apparent exception to this rule; but it only presents a single cell.

this memoir with sketches of some of the most characteristic forms.

One of the most abundant is represented by fig. 27, which I am unable, in its young state, to distinguish from Rotalia stigma, of Ehrenberg, but which I believe to be Rosalina globularis, of D'Orbigny. Its outer shell exhibits large and well marked foramina, and through which the pseudopodia have been projected.* Fig. 29 represents the soft animal dried up, and, by some fortunate accident, deprived of its calcareous covering, forming an admirable illustration of the peculiar structure so well described by Ehrenberg. Since discovering the above, I have succeeded in obtaining other specimens, after destroying the calcareous portion, by means of a weak solution of hydro-

* This and several of the other objects have been represented as they appear after they have been rendered transparent by transmitted light. We thus obtain a view analogous to what would be afforded by a section—the only way in which we can study their internal structure. At the same time the plan is very unfavourable to the identification of species, and sometimes even genera, though it is the one adopted by M. Ehrenberg. M. D'Orbigny, on the other hand, always examines them with condensed light as opaque objects—the only way in which the species can be determined, with any degree of certainty.

chloric acid. This specimen assists in the illustration of one peculiar point of their history, about which it appears to me that Ehrenberg is in error, or at least that his choice of illustrations will lead to error in others. Speaking of the Nautilus orbiculus and analogous organisms, (see page 32), and of the orifices in the calcareous portion of these animals, he refers, in illustration, to the dendritic calcareous particles of Alcyonium and other similar forms, which, by a contraction of the skin, close up the external openings, and hence he comes to the conclusion, that, amongst Foraminifera, the calcareous cell is in fact the dried up skin of the animal. Had he concluded that, as in the case of the shells of mollusks, the skin was the chief instrument in the secretion or assimilation of the compound of calcareous and animal matter, which constitutes the shell, it would have agreed with my own observations; but the inference to be drawn from his language is, that the external shell is the skin itself—the outer and harder integument which binds the soft internal organisms, and which is strengthened in the perfect animal by dendritic portions of carbonate of lime, which, on the alternate expansion and contraction of the cuticle, have the power of opening and closing the foramina.

If I am correct in my interpretations of his views, as gathered from his own illustrations, they differ materially from those to which I have been led, on a close and careful examination of a great variety of specimens.

I am disposed to believe that the calcareous portion, in which only the foramina occur, is a distinct and perfect structure, produced on a similar plan to that on which a mollusk forms its shell—a secretion from an inner skin or membrane, which separates the lime from the ocean, and contributes the animal matter required to render the calcareous particles coherent.* The inner membrane, which envelopes the soft gelatinous tissues of the living animal, is firm and strong, capable of great tension, so that the creature has the power of projecting it through the foramina in the same way as the Echinoderms push their processes through the ambulacral pores, possibly by the injection either of water or of some animal fluid. But I believe that this skin has no more to do with the calca-

* If it is not ultimately found to be a development of epithelial cell-structures, like those in shells, so ably investigated by Dr. Carpenter.

reous portion of the animal, than the shell of a mollusk has with the mantle by which it is secreted; at the same time it *is* a distinct skin, and more dense than the tissues which it encloses. The skin is unconnected with the calcareous portion, for, in drying, it often shrinks away from it into half its original compass, *within* the calcareous cell, the point of concentration being the inner margin of the spire, where it is fixed by the small necks passing through the adjoining septa. I possess a magnificent fossil illustration of this in a flint, from Flamborough Head, where the animal membrane is of such a different colour to the silicified shell, that the forms of both are stereotyped with exquisite beauty. This specimen shows a large interval between the outer walls of each cell, and the membrane by which it was originally lined; reminding one of the way in which the soft portions of Entomostraca shrink, when dried, towards the dorsal portion of their transparent cases. At the same time this membrane is firmer in its texture than the soft parts which it invests. On drying decalcified recent specimens, in order to mount them in Canada balsam, each little bag or segment is found to contain a large air globule, showing that, though the membrane shrinks up

to a certain extent, there is a point at which this stops, and then the still softer enclosed tissues dry up towards it, merely increasing its thickness in a small degree, and showing that these inner textures are little more than a gelatinous fluid. Were the whole of the soft animal homogeneous, it would, in drying, either accumulate at some one point of each cell, a small hardened mass, or it would closely invest the whole inner surface of the calcareous cell; but, as we have seen, it does neither the one nor the other, thus indicating that the inner membrane is the true skin of the animal, which invests and holds together its softer and more fluid portions, and which is itself enclosed and protected by a still harder calcareous shell.

I am aware that Milne Edwards has come to a different conclusion with reference to an allied genus of Zoophytes, (Eschara*) but in the detail of his observations, he mentions some facts which indicate a very decided difference between these and the Foraminifera, affording another illustration of the variety of the plans upon which the

* Annales des Sciences Nat. Part Zool. Vol. i. p. 25, 31.

Creator has proceeded even in the production of closely allied groups of objects. One fact noticed by Milne Edwards, is, that in the oldest formed cells of Eschara, the external lines of division become obscure, if not altogether lost, by the addition of new calcareous matter, in which the large apertures alone are left visible—arranged in quincunx,—and he justly contends that this new matter could not have come from the interior. Those who are familiar with Foraminifera, are aware that the exteriors of the earliest formed cells never lose their distinctness, by being thus externally invested with new matter, thickening their parietes.

Another fact is, that on submitting a Polypidom to the action of nitrous acid, "a brisk effervescence was visible immediately, and in some minutes the cells became flexible and separated from one another. Before treating them thus, no distinct membrane was seen on the internal walls of these cells, and when the nitrous acid had destroyed all the calcareous carbonate on which their rigidity depended, *these same parietes still existed, and had not changed their form much*; only they were formed now of a soft and thick membrane, constituting a bag, in the interior

of which we perceived the digestive apparatus of the Polype."*

This is a totally different result from what ensues on submitting a recent Rosalina or Truncatulina to the same test. In the latter case, what is left, instead of preserving the contour of the exterior, is in reality a cast of the interior of the calcareous portion, apparently the identical lining membrane, the absence of which from the cells of Eschara attracted the notice of Milne Edwards. Hence it is probable that the cell of the Foraminifer is more analogous to the poly pedom of the Hydroida, which, Dr. Johnston remarks, is "a sheath, disconnected, or at least not in organic union, with the soft pulpous matter which it invests and protects."

It must be some prolongation of this skin, or membrane, that constitutes the pseudopodia. The latter cannot proceed from the calcareous case, but from the animal contained in it, which pushes them forward through the foramina in the former. At the same time they can scarcely have proceeded as distinct organs,

* History of the British Zoophytes, by George Johnston, M.D. p. 327.

from the centre, passing *through* the elastic skin, or we should surely have found some traces of perforations in the latter, through which they could have been projected. Besides, it accords much more with what is presented by the other inferior animals—to regard the true cuticle as investing, in one form or another, all the superficial extension of the organism. This is the case in the long and beautiful pseudopodia of the Beroë, to which the analogous organs in the Foraminifera bear some slight resemblance.

Fig. 28 represents what I have frequently found in the Levant deposit, as well as elsewhere, and what I believe to be the same species as fig. 26, in an advanced stage of growth. In the young state, the cells preserve the spiral arrangement; as the growth advances, the new cells become less regular in their form, and ultimately appear to be arranged without any order whatever; the later cells have also, invariably, *two* large orifices, one at each end, giving them the shape and appearance of a number of small Cypreæ fixed upon the back of the Rosalina,—the two orifices being analogous to the communications through the septa, which connect the various segments of the soft animal at an earlier stage of

growth. This presents another striking difference from anything that has been seen amongst the Nautili, but at once reminds us of the investing Corallines. These new cells have either been soft germs, which have escaped from the interior, and fixed themselves on the backs of their parents, or they have been produced by that process of budding, or gemmiparous generation, so common amongst the lowest animals.

Fig. 30 represents an elegant species of Polystomella, allied to P. crispa. In this instance, instead of the segments of the animal being connected by *one* chain of necks passing through the septa, there are a considerable number, which, when viewed in front of the anterior cell, are seen, in this genus, to be arranged so as to represent two sides of a triangle ∴ . These apertures are situated close to the point of junction, between the septa and the lateral parietes of the cell.*

Figs. 31 and 32 represent young and old forms belonging to the allied genus Peneroplis, where, instead of the perforations being arranged

* The plate gives a less faithful representation of this animal, viewed as a transparent object, than I could have wished.

round the outer margin of the septa, they form one or more straight lines in its centre. The specimens are also represented as transparent objects, viewed by transmitted light,—by which means a section of the shell is obtained. In the young animal, Fig. 32, it will be seen that only one communicating canal connects the different cells, whilst in the older specimens, these gradually increase in number, until in the outer septa we find several.* The drawing, Fig. 32, also shews the curious thickening of the ring round the septum, which gives the projecting form to the siphuncle—the upper lip being incurved—whilst the lower one assumes the aspect of an obtuse tooth. Fig. 31 shews that the incurved appearance is continued through the whole shell, but only in the outermost series of canals.

Fig. 34 is a beautiful Planorbis-like form, of which I have not been able to identify the genus. It is curious as exhibiting no trace whatever of concamerations, though the large and beautiful

* This indicates that Ehrenberg's division of these animals into Monosomatia and Polysomatia is not a natural one, as in the young state the Peneroplis would belong to the one division, and, in its mature form, to the other.

perforations leave no doubt as to its being one of the Foraminifera. I shall afterwards have to notice a similar form found in the Lias by Mr. Strickland.

Fig. 35 represents the inferior surface of a Truncatulina, which I believe to be the T. tuberculata, a complete cosmopolite. The channel of communication between the cells is most distinctly seen along the umbilical margin of the outer ones.

Figs. 36, 37, and 38 represent various forms of the family of Plicatilia of Ehrenberg, the Miliolæ of older authors. The two former belong to the genus Spiroloculina (D'Orbigny). Fig. 38 is, apparently, a Biloculina,—38, *a*, exhibits it as an opaque,—and 38, *b*, as a transparent object. The singular forms of the Miliolæ occur at the present time in sand brought from most parts of the world. They are abundant on our own shores. I have received them from the West Indies, the Phillipine Islands, and a variety of other distant localities, whilst we shall find that analogous genera constitute the greater portion of some tertiary deposits. They are not found in rocks coæval with, or older than the

chalk. Though not distinctly concamerated, there is generally some constriction to be observed at each turn of the spire,—a rudimentary approximation to the septa of the higher forms. The construction of the lip in fig. 37 shows an approximation to the model which nature has followed in the Peneroplis, fig. 32.

Fig. 33 represents a beautiful species of Textillaria, with very distinct foramina,—a genus which is of great geological interest, as constituting so large a portion of the Chalk rocks.

Fig. 39 is an example of the curious genus Lagena. I have also observed numerous specimens of a closely allied species which occurs on our own shores—Lagena globosa—and to which I shall have to refer again.

Associated with these Polythalamian corals there are also found, in the Levant mud, numerous fragments of minute forms of Flustra and other allied Corallines.

I have also met with some examples of another class of microscopic organisms—the Siliceous

Infusoria, as they are generally designated,—specimens of the three genera, Campylodiscus, Coscinodiscus, and Actinocyclus having come under my notice. It is anything but certain that these curious and beautiful creatures do not belong to the same group as the Diatomaceæ, and that they have in reality no claim to the possession of animal life. In so many points they resemble the siliceous frustules of the former, that I cannot believe them to be distinct. Let any one, to satisfy himself of this, examine and compare a few genera in the following order, —Coscinodiscus, Actinocyclus, Actinoptychus, Heliopelta, Podiscus, Systephania, Triceratium, Zygoceros, and Biddulphia.

In Coscinodiscus, Actinoptychus, and Actinocyclus we have the elaborately ornamented circular disk. In the three following genera we find various forms of projections arising up from the external rim of these disks. In Heliopelta these are usually sharp points, but in Podiscus they are obtuse protuberances, very like those forming the angles of many Diatomaceæ. In Triceratium we have very similar appearances, only the circle has degenerated into a triangle, with

one projection at each corner.* Viewing the lateral aspect of Triceratium Favus, under a low magnifying power, it is often scarcely distinguishable from the lateral view of Zygoceros Rhombus, and of short frustules of Biddulphia aurita, both of which are well known to occur in the peculiar chains, so common amongst the Diatomaceæ. I cannot help thinking, that when our knowledge of Triceratium and its analogues is more extended, we shall find some of them also occurring in chains. Systephania, a disc closely resembling Coscinodiscus lineatus in other respects, has two of these lateral projections, which, according to Dr. Bailey, do connect distinct individuals in their young state; an exact analogue of what we find amongst the Diatomaceæ.† In passing from Triceratium Favus to Zygoceros, we lose the beautiful reticulated structure, but this returns in Biddulphia pulchella, so that it does not affect the argument. The mode of their development, also, so far as our imperfect knowledge of it goes, appears to favour the idea of a connection be-

* Amongst some objects from the Phillippine Islands, sent to me by Dr. Bailey, is a form identical with Triceratium Favus in every respect, except that it is quadrangular.

† Dr. Bailey on some new localities of fossil and recent Infusoria. Silliman's Journal. Vol. 48.

tween the Coscinodisci, &c., and the Diatomaceæ. Ehrenberg considers that the former do not occur in chains, though they exhibit the peculiar phenomenon of self-division, so common in the lower tribes of both plants and animals; a double septum being formed in the interior of the siliceous cell or frustule, which encloses the soft colouring matter, so that each half thus becomes an independent organism. The general definition of this curious mode of increase, as given by Ehrenberg, is that "Two individual bodies originate from one individual body, each of which two, possesses and actually is the half of the other, which half perfects itself to its separate and closed individuality. This completion is effected by an internal activity allied to regeneration *called into activity, by the mere tension of the parts*."* The former part of this definition appears to be in accordance with the observed facts, and, as far as the *soft* structures are concerned, the latter also; but that it can apply to those, whose hard, fragile and unyielding siliceous cases present anything but a plastic material, capable of tension, is very questionable. It appears more probable that the soft

* Taylor's Scientific Memors. Vol. iii. Art. 10.

internal organisation may separate into two parts, according to Ehrenberg's definition, but that the subsequent formation of the two transverse siliceous septa is owing to the performance of some act vaguely analogous to secretion, concerning which little is really known—each portion of the endochrome closing up its own half of the original cell, before these separate. Indeed, in many species, two new and distinct frustules form within the interior of a larger one, and are liberated only by the breaking up of the latter. This is what we see in Isthmia and Biddulphia, and is manifestly distinct from the "mere tension" of Ehrenberg.

Whatever may be their nature, the siliceous cases of these organisms occur in oceanic deposits from almost every part of the globe. In the Levant mud however, they are not very numerous, when compared with other structures. As is well known, they occur in the greatest perfection and abundance in the deposits of Bermuda and Virginia,—fields, in which Dr. Bailey and his American coadjutors have won such lasting fame. Fig. 23 represents a small species of Campylodiscus.

The next structures contained in the Levant mud to which I would direct attention, are the fragments of Pinnæ, and other shells. The examination of shell-structures, now going on in the able hands of Dr. Carpenter, has already opened a new field of enquiry, and promises to place in the hands of the Zoologist and the Geologist, an instrument of great value, applicable alike to the identification of both recent and fossil shells: — one by means of which many cases of doubtful affinity have been already cleared up, and the identification of imperfect fragments rendered much easier than before. Many of those in the Levant deposit, are thin laminæ, which have separated transversely to the direction of the prisms; but there are also numbers of these calcareous prisms, which, by the decay of the shell membrane, have been detached from one another. They exhibit a great tendency to break up in a direction parallel to the transverse lines which mark the original epithelial layers, producing small calcareous granules, of a semicrystalline aspect,—such as a very moderate amount of either chemical action, or mechanical attrition would so modify, in outward appearance, as to render the identifica-

tion of their organic origin, a matter of some difficulty. They would have much of the aspect of the crystalline atoms, found in many strata, which have been supposed to result from chemical precipitation. This tendency to separation, existing amongst shells, is important in its bearing upon the origin of calcareous rocks, and one to which I shall have to recur.

Numerous fragments of Echinodermata may also be observed. Some of these are the partially developed rudimentary plates, as in Figs. 50, 51, 52.* Others consist of the cribriform fragments of matured animals, Fig. 53—easily identified by those who are familiar with these interesting organizations. There are also some Cytheræ—minute marine Entomostracous Crustaceans—allied to the genus Cypris, so common in our fresh-water pools.

Before comparing the result of a microscopic examination of the Levant mud, with what is observed on an examination of the older strata

* See Agassiz' Monographies d'Echinodermes vivantes et fossiles—quatrième livraison. Anatomie du genre Echinus par G. Valentin. Table 5., figs. 65, 66, 67.

of chalk and limestone, I would direct attention to a few other recent and tertiary deposits, which help to illustrate the subject, and show some of the links which connect the existing with the more ancient phenomena.

On most of our English coasts, extensive deposits occur, which are largely composed of comminuted shells and corals; whilst various forms of unbroken Foraminifera and some Cytheræ are scattered through the pulverised mass. The two latter generally constitute but a small proportion of the calcareous matter, though in some cases they are much more numerous. The whole is usually mixed up with different inorganic substances, as sand, carbon, aluminous and micaceous earths, varying according to the locality from which they are obtained. On the Yorkshire coast the first two prevail. On those of Wales, especially near Tenby, the specimens I have examined contained a larger proportion of the latter, derived from the primary schistose rocks of the neighbourhood. These recent accumulations have been known to most conchologists during the last two centuries. On a detailed examination of the genera of Foraminifera found on our coasts, we shall subsequently see that they

bear a considerable resemblance to those occurring in many portions of our English Chalk. The most generally diffused are the Rotalinæ. Rotalia Beccarii and Truncatulina tuberculata (Nautilus lobatulus, Walker) occur on almost every beach. Cristellariæ are found in some localities, and in addition to these, we find forms of Textillaria, Verneueilina, Polystomella, especially P. crispa, Nodosaria, Dentalina, Marginulina, Triloculina, and Quinqueloculina, in various degrees of abundance, many of the recent British forms being identical with those found in a fossil state, Associated with these we have abundance of minute Corallines, Cytheræ, sponge spicula, both siliceous and calcareous—spines and fragments of Echinoderms, with myriads of young and broken shells. These are not mere local accumulations. The extensive beaches of the Yorkshire coast are mainly of this character, containing from ten to sixteen per cent of calcareous matter, and I presume that those of other parts of England present similar results. They do so wherever I have had the opportunity of examining them.

Portions of a similar accumulation at Key West Florida Keys, U.S., sent to me by Dr. Bailey,

exhibited corresponding results. There were various Foraminifera, especially Miliolæ, mixed up with sponge spicula, small corals, broken shells, and rudimentary plates of Echinodermata, along with a small proportion of sand and amorphous matter.

Mr. Reckitt has furnished me with some sand obtained from an interesting and somewhat analogous accumulation seven feet below the surface, at Boston, in Lincolnshire. It is unquestionably part of an ancient sea-beach. There is no doubt but that a considerable portion of the fen district to the west and south-west of the Wash, was once an estuary, which has undergone considerable changes, even since the time of the Roman Invasion, the old sea-bank having, at that comparatively recent period, been much further inland than at present.* The Boston deposit consists principally of very fine sea sand and carbonaceous matter; but mixed up with it are an immense number of Foraminifera, of several species, some of them being identical with those of the Levant. The most numerous of these are

* As in the case of the Lewes Levels. Lyell's Principles of Geol. Vol. iii., p. 210, second edition.

Rotalia Beccarii, two or three species of Polystomella, Rosalina globularis, identical with those from the Levant (Figs. 26 and 28), Textillaria —several species, one of which is identical with Fig. 33; another so closely resembling T. globulosa, (Ehr.)—the species so common in the Chalk as not to be distinguishable from it. The most interesting feature in this deposit is the comparative abundance of the genus Lagena of Walker, and our older conchologists. I have already detected L. striata, L. lævis, L. globosa, L. marginata, L. squamosa, and one or two additional undescribed species.* The deposit

* It appears that out of the genus Lagena, Ehrenberg has constructed the two genera,—Miliola and Endosolenia. Dr. Bailey has sent me Lagena striata, from the Miocene Tertiary strata of Petersburg, U.S., under the name of Miliola Ficus, which name he received from Ehrenberg, and along with it, from the same stratum, was Lagena globosa, named Endosolenia miliaris (?) This division of the genus is exceedingly proper, and shows the occasional value of examining these creatures as transparent as well as opaque objects, characters being thus sometimes discovered which would otherwise be overlooked. Lagena globosa exhibits, when thus examined, a long tube with a patulous extremity, projecting downwards from the terminal orifice into the interior of the cell, sometimes being so short as to be scarcely visible, at others so long as nearly to reach the opposite extremity of the cavity. This character Ehrenberg appears to have had in view, in employing his very

also contains numerous spines and other portions of Echinodermata, many beautiful Cytheræ, and some fragments of shell textures, amongst which Dr. Carpenter pointed out to me a fragment of one of the perforated Terebratulæ. Here we have the elements of a mixed stratum, where all the atoms of calcareous matter were once living organisms, and those chiefly minute Foraminifera, but where the siliceous portion is entirely inorganic, unmixed, to any material extent, with either siliceous Infusoria

expressive generic term—Endosolenia. After the examination of a vast number of specimens, I find that Lagena marginata and L. squamosa belong to the same genus, exhibiting a similar internal sheath, whilst L. lævis and probably L. retorta belong to the same group as L. striata—Ehrenberg's Miliola Ficus—having a long external neck or tube. It is to the internal sheath of Endosolenia that allusion was made in page 35, as constituting an apparent exception to the general rule in the structure of the Foraminifera. Lagena squamosa (Vermiculum squamosum Mont.*) is, I have no doubt, identical with the L. reticulata of Mr. McGillivray;† when viewed under the microscope, a little out of focus, the reticulations exhibit all the squamous appearance represented in Montagu's figure—an effect that would be sure to be produced by the imperfect instruments of that age.

* Montagu's Testacea Britannica. Table 14, fig. 2.

† Shells of Aberdeen.

or Diatomaceæ ; as yet I have detected neither, though some few doubtless may exist, but certainly not in sufficient abundance to constitute, in any subsequent re-arrangement of the elements, a siliceous substance resembling flint.

Recent calcareous sand, obtained from the West Indies, presents very similar appearances to what I have described in that from the Levant. We have a similar accumulation of minute and perfect Foraminifera, of the genera Rotalia, Polystomella, Peneroplis, and the group of Miliolites; a still larger proportion of fragments of the same creatures; multitudes of minute corals, belonging the groups Escharina and Celleporina; several forms of calcareous and siliceous spicula of sponges; some calcareous granules, probably derived from the disintegration of the larger corals, and a small admixture of siliceous particles,—apparently common sand.

Specimens of the newer Pliocene deposits of Barbadoes present corresponding results, with the exception that the organisms are not so numerous. The majority of the specimens which I have examined, consist chiefly of semicrystalline granules of Carbonate of Lime, which cannot be

distinguished from the residuum obtained on crushing the common Madrepora muricata; I have little doubt but that they have been largely derived from the disintegration of the hard calcareous corals, existing species of which abound in the stratum. But, along with these we find Rotaliæ, Marginulinæ, and Miliolites.

In the newer Pliocene deposits of Sicily, we obtain similar evidences of a slow organic accumulation, only in a more marked degree. Rotaliæ, Textillariæ, Miliolites and small corals, (Escharinæ and Celleporinæ) in a perfect state, are still more abundant, whilst in a fragmentary form they constitute a considerable portion of the mass. Along with them are some siliceous sponge spicula, spines of Echinoderms, and a few calcareous granules, probably derived, as before, from the hard corals and larger shells.* The

† Amongst these Sicilian deposits Ehrenberg found some strata containing multitudes of the so-called siliceous Infusoria, along with Foraminifera; and, from the apparent identity of the latter with species found in the Chalk, he concluded, contrary to the views of most other geologists, that the Tertiary strata of Sicily, were in reality Cretaceous. This erroneous opinion, however, he has since withdrawn.

specimens which I examined, and for which I am indebted to the kindness of the Marquis of Northampton, by whom they were collected, are chiefly from the limestone in the vicinity of Palermo, connected with the tertiary formations of Sicily.* Speaking of a portion of this deposit at Spaccaforno, Mr. Lyell observes, that "it is, for the most part, of a pure white, often very thick bedded, and occasionally without any lines of stratification. This hard white rock is often four or five hundred feet in thickness, and appears to contain no fossil shells. It has much of the appearance of having been precipitated from the waters of mineral springs, such as frequently rise up at the bottom of the sea, in the volcanic regions of the Mediterranean. As these springs give out an equal quantity of mineral matter at all seasons, they are much more likely to give rise to unstratified masses than a river which is swollen and charged with sedimentary matter of different kinds and in unequal quantities, at particular seasons of the year.†

However this may apply to the deposit at

* See Lyell's Principles. Vol. iii. p. 320.

† Lyell's Principles. Vol. iii. p. 220.

Spaccaforno and the south of Sicily, it obviously will not account for the origin of the same formation at Palermo, and it is not improbable that the application of the microscope to the former would lead to results similar to what we obtain from the latter.

Older Pliocene Strata.—English Crag. In this very variable deposit, the greater portion of the organised fragments consist of shells, corals, and Echinodermata. Mr. Searles Wood, in 1835, observed that amongst these, Foraminifera were abundant, as even at that time he had discovered fifty species in the lower Crag formation of Suffolk alone.* In some of the Coralline Crag of Suffolk, furnished to me by my friend Mr. Charlesworth, I found Foraminifera, especially Textillariæ, calcareous shell prisms, broken shells, small corals, and, in one instance, a stellate spiculum of a sponge, resembling those of the recent Tetheia.

In the older Miocene strata of Petersburg, in Virginia, we have various Foraminifera, especially Rotaliæ, Textillariæ, and Miliolæ, especially Biloculinæ and Spiroloculinæ, with spines of Echi-

* London and Edinburgh Phil. Mag., August, 1845, p. 86.

nodermata, Cytherinæ, and a large quantity of amorphous earthy matter. Allusion has already been made to the resemblance between some of the fossils from this stratum and those from the Boston sand. The Lagena striata and L. globosa are identical, as well as several of the Cytherinæ, and I believe also, some of the Rotaliæ.

Eocene Strata.—Paris Basin. The labours of Deshayes, Brongniart, Lamarck, and D'Orbigny, have long since made us familiar with the exceeding richness of the marine strata of the Paris basin in Foraminifera.* Some of the leading forms have been figured by D'Orbigny, Lamarck, Lyell, and others. But the application of the microscope to the deposits shews, that where they do not degenerate into arenaceous strata, they not only

* The Calcaire Grossière of that extensive basin is in certain places so filled with Foraminifera, that a cubic inch, from the quarries of Gentilly, afforded 58,000, and that in beds of great thickness, and of vast extent. This gives an average of about 3,000,000,000 for the cubic metre. (Alcide D'Orbigny on the Foraminifera of America and the Canary Islands. Edinburgh New Philosophical Journal. Vol. xxxii. p. 3. 1842.)—M. D'Orbigny also remarks, that "this group of animals is not less abundant in the Tertiary formations extending from Champagne to the sea, and its numbers are prodigious in the basins of the Gironde, of Austria and of Italy. (Idem, p. 3.)

contain, but almost entirely consist of similar organisms. In their richness, as to number and beauty of species, they almost rival the deposits of the Levant. The greater number of the forms visible to the naked eye are well known to belong to Ehrenberg's family of Plicatilia, especially to the genera Triloculina and Quinqueloculina. In some localities these abound to an almost incredible extent. Under the microscope we also find Rotaliæ, Textillariæ, beautiful forms of Peneroplis, Calcarinæ, Nodosariæ, acicular and triradiate spicula of sponges, small corals, and calcareous prisms of shell structures. The minute cementing portions of the stratum consist chiefly of fragments of the same animals. We find few of the semicrystalline granules which constitute so large a portion of the Barbadoes deposit. If these semicrystalline granules are to be ascribed to the disintegration of the hard corals, such a result was to be expected, a priori, from the rarity of these fossils in the Paris basin, when compared with some of the recent Pliocene strata in the West Indies, in which Madrepora muricata, and other species still found in the tropical seas, are abundant.* The Eocene marl of Pamunkey river,

* In 1834, Lieut. Nelson, in his paper on the Geology of Bermuda, pointed out the existence of beds of limestone

Virginia, for specimens of which I am indebted to Dr. Bailey, is exceedingly rich in various organisms, consisting chiefly of Polythalamia, spines of Echinodermata, broken shells, and calcareous shell prisms, Cytherinæ, sponge spicula, rounded sand particles, as well as small angular grains of green Silica, such as we find in our English greensand, and which have probably been derived from the destruction of some of the older strata. A Tertiary marl from New Jersey, supplied to me by Professor Ansted, of the exact age of which I am ignorant, presented very similar results.

London Clay. So small a portion of this stratum contains anything like the amount of calcareous matter found in the preceding cases, that we should not expect to find the calcareous animalculites in any great abundance; the British strata of this era contain so much larger a proportion of aluminous and siliceous elements, probably the detritus of the older rocks. Dr.

and calcareous sand derived from comminuted shells and corals. He observes, "From the most compact rock to the very sand of the shore, the materials are universally fragments of shells, corals, &c."—Trans. Geol. Soc. Second Series. Vol. v. p. 110.

Mantell has shewn that Foraminifera exist in clay obtained from a well at Clapham, and they had previously been observed by Mr. Wetherell in the clay obtained from a well, dug on the south side of Hampstead Heath.*

Mr. Darwin has kindly obliged me with specimens of many of the Tertiary strata brought by him from South America, some of which present singular differences from the majority of those which I had examined from the United States and elsewhere. In none of the specimens examined did I find one Foraminifer, and in only two did I detect any siliceous organisms. One of these was the specimen from Port St. Julian, in Patagonia, alluded to in his published Journal, as having been examined by Ehrenberg.† In this deposit, which was part of a stratum eight hundred feet thick, were a variety of siliceous discs, &c. some of them of great beauty, and a few sponge spicula. The substance of which the stratum consisted, is not in the form of rounded sand

* Trans. Geol. Soc. Second Series. Vol. v. p. 131.

† Darwin's Journal of a Voyage round the World. Second Edition, p. 171.

grains, but of particles of glassy Felspar, which exhibit a number of parallel grooves, and curious circular cavities.* This peculiar cancellated structure of the Felspathic fragments is even still more marked in the Tufaceous layer of Rio Negro. The fragments of Felspar bear no resemblance whatever to the sand grains of ordinary recent deposits. This specimen appears to contain neither Polythalamia nor siliceous organisms.†

The other deposit which contained microscopic siliceous organisms was the bone bed of Punta Alta, Bahia Blanca,‡ in which I found a few discs identical with some from St. Julian, and also a few broken spicula. No calcareous organisms were visible, but amongst the large grains of sand was much amorphous matter, which contained some Carbonate of Lime. I could, however, detect no organic structure in the calcareous particles. The deposit contains both shells and bones. I also obtained Carbonate of Lime from

* I am indebted to Mr. Darwin for pointing out to me that these particles consist of fragments of glassy Felspar, which have resulted from the long-continued attrition of erupted rocks.

† Darwin's Journal. Second Edition.

‡ Darwin's Journal, p. 83.

the Mammiferous deposit of the Pampas, at M. Hermoso, from the impure Gypseous strata of the Cordillera of Central Chili, and from most of the specimens from the older Patagonian Tertiary deposits. In those from St. Joseph's Bay were a large quantity of sand grains and much amorphous matter, which latter contained calcareous elements, along with some calcareous shell prisms. Specimens of soft Sandstone from St. Fé, abounding in extinct shells, consisted chiefly of sand grains, and appeared to contain no calcareous matter except what was in the form of broken shells and detached shell prisms. When treated with Nitric acid, there was but little effervescence.

A singular crystalline limestone from the same locality, reminded me in its aspect, under the microscope, of the Pudding-stones from the Wiltshire green sand, being full of small rounded siliceous granules, only the cementing portions consisted of a crystalline calcareous substance, in which I could not succeed in detecting any microscopic organizations whatever. It dissolved in Nitric acid with a rapid effervesence, and contained 28.54 per cent of Carbonate of Lime. One of the older Tertiary strata from Port Desire, St.

Cruz, contained sand grains, fragments of glassy Felspar, like that from the St. Julian deposit, probably a few sponge spicula, and much calcareous matter in the form of shelly fragments; the latter presenting very little visible structure. It dissolved in Nitric acid with much effervescence, containing 40.33 per cent of calcareous matter.

Specimens from Mocha, Chili, contained a large amount of sand, some glassy Felspar, and 57.61 per cent of amorphous lime, but no microscopic organisms.

Another from Coquimbo, Chili, presented analogous appearances, containing 53.79 per cent of calcareous matter, but no visible microscopic organisms.

Some from Nosidad, Chili, exhibited sand, and perhaps some glassy Felspar; some shreds and prisms of shell structures, constituted the only calcareous portions, amounting to 1.53 per cent.

A white calcareous specimen of the old Tertiary formation from the west part of the Banda Oriental, contained 56.79 per cent of inorganic

atoms of lime, along with some sand. This is a very singular and Chalk-like rock, but my specicimen contains no trace of microscopic organization.

A pure white specimen of the Estuarian marl of the Pampas,* exhibited very similar results, with the exception of a few delicate white threads resembling very small branching corals. I have not, however, been able to satisfy myself of their organic nature.

A brown coloured specimen from the same deposit contained a much larger amount of sand and silt. The lime was apparently diffused through the whole, and under the microscope was undistinguishable from the mud.

A green siliceous rock from New Jersey, very like our English lower green sand, (sent me by Professor Ansted,) in which the shells still retained their calcareous organization, exhibited large rounded grains, of very dark green sand. Amongst them were a few Foraminifera, and in some specimens numerous detached shell prisms,

* See Darwin's Journal, p. 149. First Edition.

thus exhibiting a stratum which is almost entirely siliceous, with the exception of a few minute and scattered calcareous organisms. It is possibly of the age of our cretaceous rocks.

Thus far we find that, with the exception of the South American strata, the deposits have been formed by agencies very similar to those still operating in our seas, and on our sandy beaches. That where any large amount of calcareous matter is present, such as cannot be accounted for on the supposition of detritus from more ancient strata, there we usually find either Foraminifera or disintegrated shell structures. Where we have extensive siliceous strata, containing siliceous organisms, but none of a calcareous character, we have in all probability deposits in which chemical agencies have effected great changes. But to this subject we shall have to recur. Let us now see how far down the geological scale similar illustrations are to be found.

Cretaceous Strata.—As before stated, several observers have examined the Chalk rocks since the first discovery of the fact, that they chiefly consist of minute Polythalamia. This has been especially done by M. Ehrenberg and M. Alcide

D'Orbigny, for abstracts of whose masterly papers we are indebted to Mr. Weaver.* The general result at which all have arrived is, that Chalk contains vast numbers of minute organisms, especially Foraminifera, to which the deposit principally owes its origin.

The Cretaceous strata in which the structure of these organisms appears to be the least altered, are those of the Upper Missouri, U.S., in which some of the species are identical with, and others have a close affinity to those from the Chalk of our own island; Rotalia globulosa (Ehr.) and Textillaria Americana (Ehr.) being the most common, the latter replacing the T. globulosa (Ehr.) of Europe. They still present the vitreous and transparent appearance, which characterises similar forms of Rosalinæ and Rotaliæ in a recent state; along with these, the same deposit also contains a large amount of opaque amorphous calcareous matter, very different in its character from what would be presented by the hyaline fragments of Rotaliæ, in an unaltered state.

Chalk from Dover, for which I am indebted

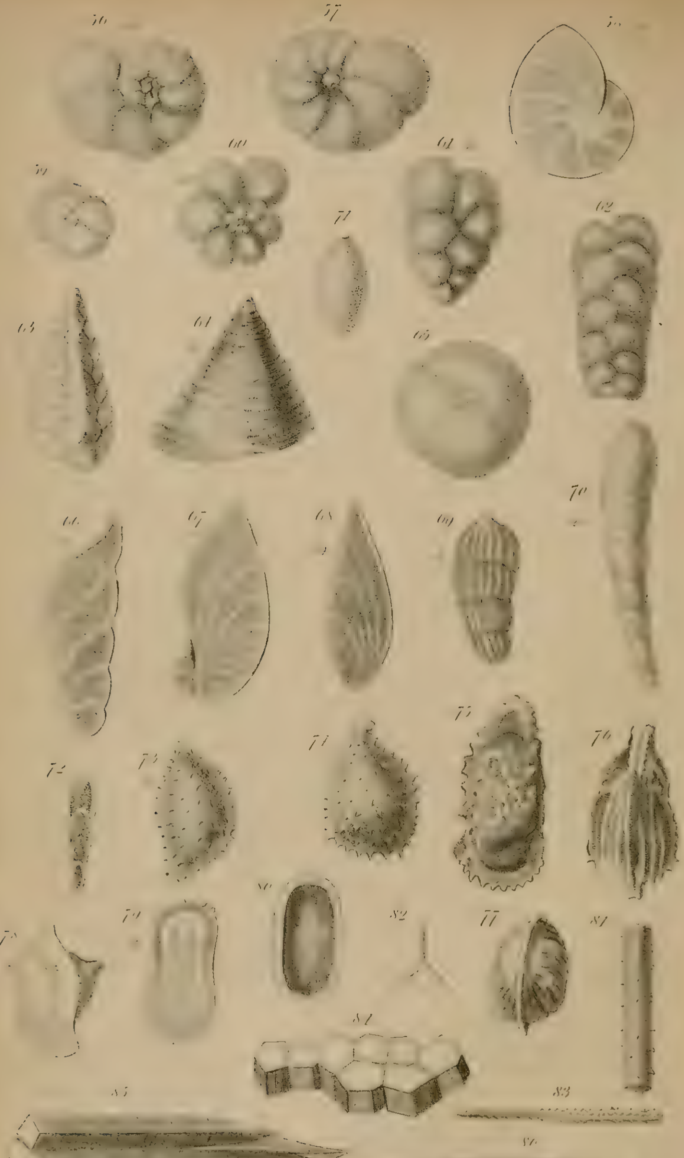
* Phil. Mag., London and Edinburgh. Vol. xviii. p. 375, and Annals of Nat. Hist. June and July, 1841.

to my friend Dr. Mantell, is exceedingly rich in analogous forms, only the finer portions are more obviously the direct result of the breaking up of the larger Polythalamia. We also find numerous calcareous shell prisms (looking very like sponge spicula), fragments of larger shells, especially Terebratulæ and Inocerami, with some portions of Echinodermata, readily distinguished by those whose eye is familiar with recent examples of the same structures.

Chalk from the midland counties presents us with similar results, varying, at different localities, as to the distinctness of the organisms, the amount of amorphous matter, and the abundance of shell prisms. The Yorkshire Chalk, which is more compact, exhibits similar structures, though they are less easily separated from their amorphous cement, and in some specimens so broken up as to present few perfect organisms ;—as if the newly forming stratum had been acted upon by gentle aqueous currents, which had transported the more minute atoms to another locality, where some local interruption to the current allowed this sediment to be re-deposited, giving rise to layers of denser structure and finer grain. The Red Chalk, which is of a bright red colour,

from being loaded with an oxide of iron, presents identical organisms. They also exist still lower down, in the Grey Chalk, which passes into the blue clays of Speeton.

William Harris, Esq. of Charing in Kent, and Dr. Mantell, have submitted to my inspection specimens of a deposit of chalky marl, which was discovered by Mr. Harris, at the foot of the Chalk hills, at Charing. The deposit, resting upon the upper Green-sand is about a foot thick, chiefly consisting of soft white tenacious clay; but contains vast numbers of the beautiful Foraminifera, and other organisms characteristic of the Chalk, and which Mr. Harris has distributed with the utmost liberality amongst those who are interested in the subject. Its origin appears to be somewhat obscure, but, as Mr. Harris suggests, the most probable explanation is, that it was formed at the time the Chalk hills obtained their present undulated contour, and that the deposit in question was some of the resulting debris. Plate 4, is devoted to some of the very beautiful organisms which the clay contains. They are easily separated by washing, and become as clean and perfect as they could be, even in the most recent deposits.



J Stephenson &C° Sc

In addition to what I have enumerated, the deposit also contains several additional species of Foraminifera and Entomostraca, which I have not figured, as well as a great variety of Amorphozoa, Zoophytes, Anellida, as well as fragments of various Crustacea, Echinodermata, Conchifera, Brachiopoda, and Cephalopoda, along with small teeth and bones of fishes, which have been found in it by Mr. Harris.

Figs. 56 and 57 represent the upper and under surfaces of a large species of Rotalia of Ehrenberg, but which may belong to D'Orbigny's genus Rosalina. I cannot perceive the oral aperture which, by the present mode of classification, is necessary to the positive identification of the genus. This species is very abundant.

Fig. 58 I believe to be the Rotalia (Planularia) turgida of Ehrenberg. It belongs apparently to the genus Robulina of D'Orbigny. The aperture is distinctly at the external angle of each cell, and not at the inner border, as in Rotalia.

Fig. 59 is probably the early condition of some other species, though the small central disc on

one side resembles Anomalina (D'Orbigny); various modifications of it are abundant—some with no traces of divisions into cells, others with two or three. It can scarcely belong to fig. 56, as the latter shows the division into minute cells to the apex of the spire. It has the central disc of an Anomalina.

Fig. 60 is the Rotalia globulosa of Ehrenberg, of which exquisitely beautiful little specimens occur not unfrequently.

Figs. 61 and 62 represent forms of Textillaria, which vary considerably.—Fig. 61 is, appparently, the T. globulosa. (Ehr.)

Fig. 64 exhibits a front view, and 65 the base of what is probably some genus allied to Textillaria. It is an indistinct spiral, of a trochoid form. In some parts of the spire there are vague traces of divisions into cells. The base, fig. 65, exhibits a well marked terminal cell, occupying nearly the half of the circle. The smaller depression is apparently but partial, and does not constitute a septum.

Fig. 63 probably belongs to D'Orbigny's genus

Verneueilina. It is triangular, the edges being sometimes sharp and produced. The lines of division into chambers are very indistinct. The species is common. This species, or one very closely resembling it, is in the cabinet of Mr. Bean, of Scarborough, who obtained it from the Irish coast, and who also possesses, from the same locality, specimens not to be distinguished from figs. 61, 62, and 64. In the recent state, all these forms present an opaque aspect, very different from the glassy transparent appearance of the Levant Textillaria. The fossils exhibit the same opacity.

Fig. 66 is a species of Marginulina, there being a distinct projection at the superior angle of the last chamber, in which the terminal orifice is situated.

Fig. 67 is a beautiful Cristellaria (D Orbigny), exhibiting an excellent illustration of the tendency of the straight forms to assume the spiral type. It is little more than a straight Marginulina, with the young cells incurved.

Fig. 68 is probably another species of the same genus.

Figs. 69 and 70 are two species of Dentalina (D'Orbigny). In the former, the cells are longitudinally striated, and in the latter smooth I have seen some examples like fig. 69, but in which the axis was straight, instead of being curved, and which, consequently, would belong to D'Orbigny's sub-genus Nodosaria. Fig. 72 exhibits a small sectional view of fig. 70.

Fig. 71 belongs to the recent genus Lagena, or to Oolina of D'Orbigny.

Of the nature of the two bodies figs. 73 and 74, I have not been able to form an opinion. They are small flask-like objects, curiously echinulate, the projecting spines being sharp and transparent. They very much resemble some recent Lagenæ, only the latter are, I believe, always equilateral. Mr. Harris suggests that they may be fragments of Dentalina aculeata, D'Orbigny.

Fig. 75 represents a lateral, and fig. 76 a dorsal view of a very beautiful Entomostracous animal, which may be conventionally arranged under the genus Cytherina. It is remarkable for the singular series of marginal tubercles, or projec-

tions, of which the arrangement varies in different specimens, the row fringing the broad extremity, being the most constant. The irregular projecting surface is marked with delicate reticulations. As I believe it has not been figured, it may be provisionally called C. echinulata.

Fig. 77 is either another species, or, what is possible, a young state of the last.

Fig. 78 is an exquisitely elegant form, belonging to the same class of objects. It is shaped like an Arca, with two lengthened projections at the umbones. I have seen several specimens of it. C. umbonata would be an appropriate name.

Fig. 79. Some forms of this species seem to approach to young states of fig. 75. It is possible that they may be identical. Many recent Entomostraca vary considerably at different stages of growth. As, however, I have seen several specimens of it, and they seem constant in form, the name of C. serrata may be given to it.

Fig. 80 is the most common species, examples

of it being of frequent occurrence. Recent species closely resembling the above forms, occur in modern beach deposits.

Fig. 81 is almost the only fragment I have seen in the Charing Chalk really resembling a sponge spiculum, of which it may possibly be a portion.

Fig. 82 is a calcareous tri-radiate sponge spiculum, from Chalk found, by Dr. Mantell, in the interior of a hollow flint :

Fig. 83 is a siliceous sponge spiculum, found abundantly along with the last.

Fig. 84 is a fragment of shell, and figs. 85 and 86 are detached calcareous shell prisms, which are very abundant in the Charing Chalk. At first I was led to suppose that these were large calcareous sponge spicula, but, on further examination, I was convinced that they were shell prisms, and that the analogous structures found in flint were of the same nature. I am happy in having had an opportunity of obtaining Dr. Carpenter's confirmation of the views

which I ventured to publish,* on the character of these curious forms. After examining my specimens, he had no doubt but that they were the separated prisms of shells, probably Inocerami.

I have noticed all these minute organisms somewhat in detail, as they afford one of the most interesting examples of the variety of microscopic fossils which constitute Chalk that I have met with. With one or two exceptions I have not ventured to attach any specific names to the Foraminifera, many of which are probably included in M. D'Orbigny's catalogue ;† but as neither descriptions nor figures accompany the list, and I have had no opportunity of consulting the plates accompanying his original memoir, I have no means of identifying them ; and to coin new terms would only be to add to the confusion which is already too great, owing to the fact that D'Orbigny and Ehrenberg are adopting two distinct and independent systems of specific nomenclature, based upon different modes of observing.

*On the real nature of the minute bodies in flints, supposed to be sponge spicula. Annals Nat. Hist. Vol. xvii. p. 467.

† Phil. Mag. Lon. and Edin. Vol. xviii. p. 416.

The ferrugineo-calcareous matter obtained from the decomposing sponges of Flamborough Head, contain abundance of large and perfect Foraminifera, and in some specimens calcareous sponge spicula are distinctly present. All that I have examined contained a much larger proportion of sand grains, than occurred in the surrounding Chalk. Thin argillo-calcareous partings separate the horizontal beds of Chalk at the same locality, but they exhibit nothing more than a few Foraminifera, amongst some sand, and much amorphous argillaceous matter. They evidently indicate the occasional overflow of muddy water, from some source not far distant. The partings do not usually extend over very wide areas, but appear to have arisen from local causes. Siliceous granules are more or less abundant in every specimen of Chalk which I have seen, and also in that taken by Dr. Mantell, from the hollow flint. The lime of some of the calcareous Rotaliæ from the chalk in the same flint has disappeared, and its place been supplied by pure and transparent silex, which is the condition of nearly all the Foraminifera found in the solid flint—a curious illustration of the preference manifested by the siliceous

matter for combination with animal organisms. The fact has been already noticed by Ehrenberg.*

The hard Chalk of the North of Ireland also abounds in Polythalamia, though they cannot be separated from the consolidated matrix; but when splinters are broken off, the contour of the shells is marked by translucent lines in the opaque stone, showing that they once existed there as abundantly as in the English Chalk. The consolidation of the stratum from contact with erupted rocks, has obviously altered the appearance of the minute fragments, which, in the friable Chalk rocks of Cambridge, look almost like amorphous lime, but which, in the Irish stratum, can no longer be identified as organic atoms; — an interesting example, conducting us to the more solid limestones from whence nearly all traces of microscopic organisms have disappeared.

The latter appears to be the case with part of the Chalk strata of the Lebanon range. Though in some of these Ehrenberg found Foraminifera, I could not detect any traces of them in the cream-coloured limestones of the Gebel Suneen

* Phil. Mag. Lon. and Edin. Vol. xviii. p. 397.

above Beyrout. Nature has here gone a step beyond what she has accomplished in the Irish Chalk, and obliterated not only the fragments, but the perfect Polythalamia, with the exception of a few scattered translucent points, which may be the faint remaining indications of the once organic condition of the whole mass.

The Blue Clay of Speeton, the Yorkshire representative of the Neacomian series, abounds in Polythalamia. From one specimen, not more than 1½ cubic inches in bulk, I obtained examples of at least five species, consisting of two specimens of a small Nodosaria, two of a Marginulina, two of an Oolina, or same genus identical with fig. 71, about forty specimens of a beautiful little Cristellaria, and above one hundred of a curious form of which I have not yet identified the genus. These, along with a few Entomostraca, and small fragments of shell structures, constituted the only calcareous elements of the stratum. I was much interested in receiving from Mr. Harris a Marginulina and a Cristellaria which he had found in the Gault of Folkstone, both of them identical with my Yorkshire species, as well as a third beautiful form which was new to me.

Of the original character of the calcareous rocks below the Chalk, our knowledge is imperfect, owing to the chemical changes they have obviously undergone since their deposition. To a large number of the Oolitic rocks especially, a pisolitic structure has been given which, in all probability, they did not originally possess. This has been illustrated, by Mr. Lyell, in the case of the larger concretions of the Magnesian Limestone,* and there is little doubt but that somewhat similar changes have been produced in the roestones of Bath and Yorkshire, and the pisolites of Carlsbad. The original state of the calcareous matter to which a pisolitic structure has been subsequently given, is not easily ascertained; but if it was in the form of minute organisms, such as have been described, owing to their small size, they would be more rapidly destroyed by chemical agents than the larger structures; what would be sufficient to obliterate the one would produce little visible effect on the other. Hence, in supposing their original existence in these rocks, we are supported by analogy, especially when we remember the close general resemblance between the *larger* fossils in the Coral and Bath Oolites, and those

* Elements of Geol. p. 77.

of the Chalk, as well as of the existing warmer seas, where Polythalamia abound; whilst we are going in opposition to analogy in having recourse to some mysterious theory of chemical precipitation, —a process which scarcely finds an illustrative parallel in the unaltered strata of either the Cretaceous, Tertiary, or recent eras. Observation also confirms the probability of this, by shewing that similar Foraminifera and other minute organisms do exist amongst the older strata, as well as amongst the more recent ones; these microscopic forms having occasionally escaped the obliterating influences that have caused such an extensive destruction amongst the greater number.

M. Ehrenberg has already discovered Foraminifera in the compact flints of the Jura Limestone, at Cracow. In one or two instances, I have succeeded in detecting the soft animal, closely resembling fig. 29, calcified and enclosed in a pisolitic granule, from the Yorkshire Coralline Oolite, and have also found well-marked evidence of their existence amongst the oolitic granules of the Bath Oolite. Dr. Buckland quotes the discovery of microscopic shells in

the Stonesfield slate, by Mr. Darker,* — proof positive that they were once present, and in all probability in great numbers.

Mr. Strickland has published figures and descriptions of two forms of Foraminifera, under the genera Orbis (Lea) and Polymorphina, from the Lias of Wainlode Cliff, in Gloucestershire.† He remarks that the first of these exhibits no concamerations. and, consequently, should perhaps be regarded as a Serpula. Fig. 34, from the Levant, presents an exactly analagous contour, only the latter exhibits large foramina; but I have seen other species from the same deposit scarcely distinguishable from Mr. Strickland's figure.

The beautiful little fossil found by the late Mr. Bowman, in the Mountain limestone of Derbyshire, and named, by Mr. Phillips, Endothyra

* Dr. Buckland on the agency of animalcules in the formation of Limestone. Edin. New Phil. Journal. Vol. 30, p. 44.

† Quarterly Journal of the Geological Society, London. Feb. 1846.

Bowmanii, is unquestionably a Foraminifer, almost identical in its internal structure and the arrangement of its cells, with the Fusulina of the Russian limestones, confirming the discoveries of Messrs. Tennant and Darker of the existence of microscopic shells amongst the Carboniferous deposits.* Dr. Dale Owen met with well characterised Polythalamia in the oolitic portions of the Carboniferous (Penthremite) limestone of Indiana.† Mr. Phillips states that they occur in the Palæozoic limestones of Carrington Park and South Devon,‡ and Sir R. Murchison has recorded the existence of limestones belonging to the uppermost members of the Carboniferous series, which through a vertical extent of at least two hundred feet, are charged with Fusulinæ,—Foraminifera allied to Alveolina. In one part of the deposit are bands of pure white Fusulina limestone, varying in thickness from fifteen inches to five feet.§ Many of the above Palæozoic rocks have likewise obtained some calca-

* Dr. Buckland ut supra, p. 44.

† Silliman's American Journal. Vol. xlvi. No. 2, p. 311.

‡ Phillips' Palæozoic Fossils, p. 153.

§ Murchison's Geol. of Russia in Europe. Vol. I. p. 86-7.

reous matter from the shells of Entomostraca, which are often exceedingly abundant; especially in strata connected with the Carboniferous era.*

From the above series of facts some important general conclusions may be drawn.

As geologists have long been aware, the bed of the Levant consists of an extensive calcareous deposit, now in process of formation, which deposit is known to extend into the Adriatic, and, in all probability, also into the western parts of the great Mediterranean basin. It appears that this deposit consists mainly, if not entirely, of minute forms of organised structures. Some of these are apparently vegetables, belonging to the siliceous group of Diatomaceæ. Some are of still more questionable affinities, as spicula of sponges, and the siliceous cases of organisms considered, by Ehrenberg, to be Infusoria,—Naviculaceæ, Coscinodisci, and Actynocycli; others are undoubtedly animals, as Foramini-

* Why these Entomostraca should so often be referred to as indicating the existence of fresh-water, I am puzzled to understand. They are much more abundant in the sea than in any of our lakes and rivers.

ferous corals, which constitute an important part of the whole; chiefly belonging to Ehrenberg's groups of Textulinaria, Rotalina, Helicosorina, and Plicatilia, associated with which are various species of Flustra and other soft corallines. Co-existing with these in considerable quantities are portions of crustaceans and Echinodermata, various broken shells, and small calcareous granules,—the fragments of separated shell prisms; whilst the only atoms which appear to be inorganic are some siliceous grains, apparently common sand.

Also, that analogous accumulations are taking place in other parts of the world, especially evident in the case of the beaches accumulating on the shores of existing seas; but that in some of these, especially on our own coasts, Foraminifera and other perfect microscopic organisms are less numerous, the preponderance being in favour of broken shells, mixed up with minute crustaceans and fragments of Echinoderms, along with various proportions of inorganic detritus, especially sea sand.

That throughout an extensive range of Tertiary strata we have undoubted proofs that the operation of similar agencies led to their accumulation, and

also that similar causes led to the formation of the Cretaceous strata of both Europe and America.

That in the strata below the Chalk the evidences become more obscure, owing, probably, to some extensive metamorphic action that has modified their structure, but that glimpses may occasionally be obtained, indicating the existence of similar phenomena, even as low as the Silurian limestones.

That though in some strata, as in the Chalk, Foraminifera have been the *principal* instruments in effecting these results, in others, sponges, corals, molluscs, Echinoderms, and crustaceans have contributed their quota to the entire mass, and often in much larger proportions than the Foraminifera themselves. This distinction appears to mark the difference between the deposits formed along exposed coasts and those accumulating in the deeper or more sheltered seas; in some instances, as in the Coralline Oolites of Yorkshire, Oxfordshire, Berkshire, and Wilts, we find the remains of vast coral reefs regularly imbedded in the stratified mass, and most probably still occupying the position they did when tenanted by living polypes.

That as regards the siliceous elements of calcareous strata, few recent deposits exist in which there are not some siliceous cases of the organisms, regarded by Ehrenberg as siliceous Infusoria, but that in the majority of instances, grains of sand constitute the only visible form in which silica exists in any abundance. In this state it is found more or less in all.

It is obvious, then, that if any calcareous deposits are now forming, the results of chemical decomposition, they are not in accordance with the ordinary plan followed by nature in the accumulation of calcareous strata either at the present, or during the Tertiary and Cretaceous periods. At the same time, we must not lose sight of the fact, that calcareous deposits *may* be formed under water, the results of chemical action alone. The Travertins of Italy afford sufficient evidence of this; and if similar calcareous springs existed extensively under the waters of any confined ocean, there is no apparent reason why they should not lead to the production of calcareous deposits, such as are found at San Vignome and at San Filippo. The only approach to an appearance of the kind which has come under my notice, in all the specimens of recent sediment which I have examined, was in

the mud from Charlestown harbour, U.S. which, as has been already noticed by Dr. Bailey, contains detached rhombohedra of carbonate of lime, so perfect as to leave little doubt but that they are the direct result of some chemical action, and are not derived from the recent destruction of calcareous organisms. I was interested on finding similar crystals amongst Foraminifera, brought up from an Artesian well sunk at Charleston, at a depth of near two hundred feet; so that those in mud may be derived from the older deposit, with which the stream may come in contact in some part of its course. The existence of Foraminifera in the recent esturian mud renders this somewhat probable; but, on the other hand, in the latter instance, the rhombohedra are so much more numerous than the Polythalamia, as compared with their relative proportions in the borings from the Artesian well, that, if they have been so derived, it has been from some portions of the stratum where the crystals were much more abundant than at Charlestown. At the island of Ascension, Mr. Darwin found that the sands on the beach had been consolidated by calcareous matter deposited from the sea water, in which it was held in solution. The calcareous matter

also incrusted the rocks of the vicinity.* An analogous agency has doubtless consolidated the hard sandy portions of the Chalk rubble covering the Chalk rocks on the south side of Flamborough Head, on the Yorkshire coast. An instrument that could do so much might do more, and may possibly have produced the crystalline limestone of St. Fe, as well as the white calcareous rocks of the Pampas and the Banda Oriental.

An exceedingly interesting subject for enquiry now suggests itself. In the recent deposit of the Levant, we have generally an admixture of calcareous and siliceous organisms. In some localities the latter are more sparingly distributed than in others; in a few instances they are almost entirely absent. The same admixture occurs in the recent sands from the West Indies; the soft calcareous mud from the bottoms of the lagoons of the coral islands, contain a considerable number of similar siliceous forms;† and corresponding results have been obtained in most of the marine sediments from various parts of the globe, examined by M. Ehrenberg.

* Darwin's Journal, p. 578. First Edition.

† Darwin's Journal. Second Edition, p. 465.

On the other hand, the Infusorial deposits of Bermuda and Virginia are altogether siliceous. Not one calcareous organism exists. The siliceous forms comprehend the majority of those which I have described from the Levant, many of them being not only *similar*, but *specifically identical*, and the manner in which they are grouped together in these distant localities indicates something more than mere accident; indeed we want nothing but the calcareous structures, to render these Miocene strata* perfectly analogous to those now in process of formation both in the Mediterranean and in the West Indian seas. Are these siliceous deposits, so void of any calcareous organisms, still in the condition in which they were originally accumulated? or were they once of a mixed character, like those of the Levant, having been subsequently submitted to some chemical action, which has removed all the calcareous forms, leaving only the siliceous structures to constitute the permanent stratum? I am disposed to adopt the latter opinion, for several reasons:

* Dr. Bailey informs me, that the Virginian deposits belong, beyond doubt, to the Miocene era. That from Bermuda is more doubtful.

1. When the contents of the stomachs of many mollusks are examined, they contain a mixture of calcareous and siliceous organisms. When this is acted upon by Hydrochloric acid (especially in the case of Pecten Maximus, as shewn by Dr. Mantell and Mr. Hamlin Lee) the result is an accumulation so identical with that from Bermuda as to be most readily mistaken for it. The same thing is still more forcibly manifested when Ichaboe guano is treated with boiling Nitric acid, until all the calcareous and phosphatic portions are destroyed,—the discs, spiculæ, and other organisms, then exhibiting the most striking identity with the American strata.

2. Such deposits, in their present condition, stand out as anomalies in the existing order of oceanic phenomena, and have nothing resembling them except the local fresh-water accumulations which occur in various places. Between these, however, no real analogy exists. It must not be forgotten that the Virginian deposits can be traced for above two hundred miles; and, being marine, would most probably be mixed up with such marine products as were likely to occur along so extended a line. The only recorded instance with which I am

acquainted, that exhibits the slightest resemblance, is furnished by M. Ehrenberg, in his examination of materials brought home from the South Pole, by Dr. Hooker. Some pancake ice, obtained in lat. 78°10′ W. long. 162°, when melted, furnished seventy-nine species of organisms, of which only four were calcareous Polythalamia, the remainder being all siliceous.* But even this example, remarkable as it is, does not supply us with any real parallelism. The deposits in question have never yet exhibited a single example of a calcareous organism. In reply to my query, as to whether there were any local geological phenomena incompatible with the view I entertained, Dr. Bailey observes, "There can be little doubt but that the Polythalamia have been removed from our marine tertiary Infusorial beds, by some chemical action, which action has also attacked the large mollusks, so as to leave only the casts of their shells. Wherever the mollusks are preserved, there are the Polythalamia also." This is most confirmatory. We may then safely conceive that an analogous change has been effected in the Bermuda deposit, where also

* Ehrenberg on Microscopic life at the South Pole. Annals Nat. Hist. Vol. xiv.

we have only siliceous organisms. It becomes probable that many of our European Green-sands, and other siliceous strata, however barren of such structures they appear, may have once contained multitudes of calcareous microscopic organisms, some of which have been removed *after* the consolidation of the strata, leaving either hollow casts, or having had the cavities subsequently filled with Silica, as in the case of the shells at Blackdown; in other instances the change may have taken place whilst the deposits were soft, when the siliceous sand would be pressed down into the spaces previously occupied by the animal body, and thus all traces of the organised structure might permanently disappear.

Nature furnishes us with an agent quite equal to the production of such effects as we are at present acquainted with. This is carbonic acid gas, in solution in water. Mr. Lyell has already availed himself of this instrument to account for the subtraction of calcareous matter from imbedded shells, as well as for some of the changes that have taken place in the structure and composition of stratified rocks.* He has also recorded one

* Principles of Geol. Vol. i. p. 318. Second Edition.

instance, near Clermont, where this process is still going on, the lime being partially dissolved and rendered soft,—the quartz alone remaining unattacked.* Carbonated water has, in all probability, produced some of the changes which the calcareous organisms of strata still retaining much carbonate of lime, but without any visible organic structure, have undergone.

The pisolitic structure of many Oolitic rocks has been referred to. It occurs more commonly than is generally imagined. Sir R. I. Murchison found it in extensive Miocene deposits in Southern Russia. Similar appearances are presented by beds of the same age in Styria and Hungary.† It is more or less common amongst all the Oolitic strata, and is seen in the Carboniferous rocks of Indiana, U.S.

On examining thin sections of oolitic limestone from Bristol, Durdham Down, Yorkshire, and Skerry, I found that the granules in these specimens, composed of the well-known concentric layers, were imbedded in a crystalline matrix.

* Principles of Geol. Vol. i. p. 317. Second Edition.

† Annual Address to the Geol. Soc. By Leonard Horner, Esq. 1846: p. 49.

I was able to ascertain, also, that the former had not only been produced, but hardened, prior to the crystallization of the latter; as in many instances the granules were split across with a clean fracture, sometimes a dozen or more of them being so divided in one line, and the broken portions held asunder by the same crystalline structure which separated the perfect granules.

It is easy to conceive, that whilst these strata were in a less consolidated state than at present, they might be charged with water containing carbonic acid gas. This would act as a solvent of the organic atoms of lime until the acid was neutralised, and the fluid saturated with the alkaline carbonate, which would now become obedient to the ordinary laws of aggregation and crystallization; and, on the recurrence of any material change in the electric condition of the whole, the lime might be redeposited at different periods, and in a variety of forms,—amorphous, crystalline, or concretionary, depending upon delicate and inappreciable causes, of the nature of which our knowledge is very imperfect.*

* Most probably these causes are of an electric character,

That springs possessing a solvent power exist, is proved by their prevalence in most limestone districts, producing Travertins and Tufas, but more especially in volcanic regions. These Tufas are apparently formed at the expense of the older calcareous strata. It is also evident that currents charged with solvent gas may pervade individual strata for a long series of ages, and eventually rob them of all their lime, without materially affecting the rocks either above or below. A thin parting of clay may suffice to direct individual currents, and cause them to flow in one direction with amazing constancy for a long time. This is shewn by many mineral springs, and especially by those of Harrogate. In the garden of the Crown Inn, springs respectively charged with sulphuretted hydrogen and iron bubble up clear and sparkling, within a few feet of each other, and have done so for an indefinite period. Similar phenomena exist

acting under various circumstances of heat and pressure, both of which have clearly exercised a powerful modifying influence. The consolidation of the Irish Chalk, as compared with that of England, owing to the superincumbent mass of ancient Trap, is an illustration of these latter modifying causes. The degree of saturation of the calcareous fluid would also have some inflnence over the result.

on a moor near the same place. The slightest communication between them would make them both of an inky blackness. They apparently derive their mineral contents from different strata, which are being slowly, but surely, robbed of their mineral contents; and thus Tertiary deposits may have been deprived of all their calcareous organisms by a slow and long-continued process, which has left the insoluble siliceous structures alone undestroyed.

It may be objected, that no such explanation as this will apply to those extensive Limestone rocks already alluded to, where the calcareous matter still remains, though with an obviously altered structure. In such cases the lime has not been removed. This does not materially affect the argument. It only shews that a double process of interstitial solution and re-deposition or crystallization has been going on at the same time. However difficult to explain, the fact may be considered certain, as it is capable of the most satisfactory illustration. It is proved by the spines and plates of Echinodermata, found in the Oolitic strata, where, though the atoms of lime still retain the exact form, and exhibit the beautiful reticular structure of the living organism,

yet their arrangement and character have been so altered that the spine, when fractured, breaks up, not in the direction of the organization, but along the lines of cleavage, characteristic of calcareous spar, and that nothing is easier than to obtain out of one of these spines a number of perfect rhomboidal crystals, which nevertheless exhibit, under the microscope, all the interesting structure which Dr. Carpenter has shewn to be peculiar to the Echinodermata. Here is obviously an instance of double action. The place of each atom, as it was removed, must have been supplied by another of the same substance, only it has been rendered obedient in its re-deposition to the laws which regulate crystallization, rather than those of organic life. At the same time, why the larger organisms should retain their original structure and contour, whilst the microscopic forms alone are replaced by pisolites, roestones, and crystalline limestones, is a question that I am unable fully to answer. Analogous phenomena, however, exist elsewhere, which shew that an extensive metamorphic action, either chemical or volcanic, sufficiently powerful to destroy all the smaller organisms, does not of necessity affect the integrity of the larger fossils. Sir R. I. Murchison has recently shewn us that very extensive

changes may be effected in the atomic structure of calcareous rocks, and, consequently, in all the microscopic organisms not materially larger than the amorphous atoms of the rocks, without involving the destruction of their fossils. He has given an interesting example of this in the little oasis of fossiliferous Carboniferous limestone at Cossatchi Datchi in the neighbourhood of the Ural, where a patch of limestone surrounded by eruptive rocks has been thrown up into calcareous hummocks, an appearance compared by the author to the hornitos of the Mexican Jorullo. This effect Sir R. I. Murchison ascribes to heat and gaseous vapours which formerly struggled for expansion, and which have obliterated all lines of stratification, and rendered the limestone as pulverulent as sugar; yet it abounded in interesting fossils.* In the valley of the Miass also he found Encrinites in a pure saccharoid limestone, which had also been highly altered by neighbouring, eruptive works.† These instances prove how large an amount of change may be wrought in the atoms of a rock by gases, under the influence of volcanic heat, without obliterating its larger

* Geol. of Russia in Europe. Vol. i. p. 439.

† Idem, p. 426.

fossils; still more easily can we conceive of water containing carbonic acid slowly destroying the smaller organizations of a Foraminiferous limestone without producing any very great effect on the larger structures. The solvent would act upon the surfaces of the large and small fossils with equal rapidity; but what would obliterate a Foraminifer, the two or three hundredth part of an inch in diameter, would produce but little change on the surface of a thick shell.

There are still many difficulties to be encountered in the settlement of this great question. There is no doubt but that some strata, even of recent date, which contain multitudes of Foraminifera and other small organisms, both entire and in fragments, also contain large quantities of amorphous calcareous matter which cannot be *directly* traced to any such origin. The chalk from the Missouri has been already alluded to as of this character. It is not impossible that the opaque portions of the Missouri chalk may in reality be the exuviæ of the lower animals; and that the latter may have been the instruments of an extensive conversion of lime from an organized to an amorphous form. In the above instance it is obvious that no external agents, acting gene-

rally upon the whole mass, can have produced the change from a transparent and organized to an opaque and inorganic condition, or all the fragments of the minute Foraminifera would have been more or less affected in the same manner. But such is not the case. The latter retain their vitreous transparent aspect; hence the amorphous part of this deposit must either have been derived from some other source than broken Foraminifera and analogous minute structures, or it must have been altered by some agency acting only upon *some* of the atoms now constituting the stratified mass. The digestive organs of molluscous, acephalous, and other marine animals appear to be the only instruments which would be likely to effect such results. We have the *copros* of saurians and of fish constituting extensive stratified layers,—why, then, should we not have the *excreta* of molluscs and other inferior animals? Mr. Darwin met with two species of fish in the neighbourhood of Keeling Island belonging to the genus Sparus, which feed entirely on coral. On opening their intestines, he observed them to be distended with yellowish calcareous matter; and he adds:— "These fish, together with the lithophagous shells and Nereidous animals, which perforate every block of dead coral, must be very efficient

agents in producing the finest kind of mud; and this, when derived from such materials, appears to be the same with Chalk."* May not much of the amorphous calcareous matter which occurs in the Coralline Oolite of Yorkshire have been treated in this way? Lithophagi are abundant in the deposit; Modiola inclusa is still fixed in the hard corals into which it had bored; whilst the rounded and enamelled teeth of the Malton fish are such as would be well adapted to crushing calcareous organisms.

If a few soft fluviatile Infusoria are put into clear water, with nothing to feed upon except beings like themselves, it is surprising what an amount of their exuvia is accumulated in a few days. If we allow a similar process to go on amongst larger animals only feeding upon small calcareous creatures, instead of the soft tissues of Infusoria, we may readily conceive that in the space of hundreds of years an enormous amount of amorphous calcareous matter would be accumulated. Even those animals which are phytophagous must contribute to this, for they cannot feed upon a single marine plant without

* Darwin's Journal. 1st Edition, p. 553.

devouring multitudes of the calcareous Polythalamia, Escharæ, and other parasitic corals, with which most marine Algæ are loaded.

Something analogous to this has taken place at the time of the accumulation of the guanos of Ichaboe and Peru. It is obvious that all the vast multitudes of siliceous Infusoria which they contain have been taken up by the birds whilst in the stomachs of molluscs and other soft animals. That the latter feed largely upon them is abundantly proved; and when we remember with what a formidable rasping apparatus the palates of many of these creatures are armed, we shall cease to wonder that they can grind either calcareous or siliceous structures to powder. Amongst the Russian Fusulina limestones already noticed, I mentioned that portions of the series exhibited bands from fifteen inches to four or five feet thick, consisting entirely of Fusulinæ; but above and below these the Polythalamia diminish in number until at length only a few specimens are found, along with other fossils, scattered through the limestone. In the latter instance it is evident that, in addition to what has been contributed by the calcareous cases of the Fusulinæ, there has been, as in the example of the Missouri Chalk, a

considerable amount of calcareous matter derived from some other source than the mere breaking up of the Foraminifera, and the metamorphic condition of which has been produced without destroying the contour of the latter small animals. How far may calcareous excretions have existed here? At the same time, such strata as the limestone of Santa Fé and the white calcareous marl of the Pampas seem to indicate, in addition to organic causes, either chemical deposition or the extensive instrumentality of some agency that has altered the appearances of the rocks subsequent to their deposition.

The strata of Magnesian limestone and crystalline Dolomites, present new difficulties in the way of accounting for the origin of *all* calcareous rocks by the operation of vital causes. They contain various proportions of magnesia and lime, amounting, in many instances, to as much as 45.82 per cent of the former, to 54.18 of the latter.* Now, no organisms that I am acquainted with would have separated these two earths from their state of solution in the sea-water, in anything like the above proportions. Even the bones of

* Rammelsberg, Handwörterbuch der Mineralogie.

animals do not contain above 1 per cent of phosphate of magnesia, to about 62 of carbonate of lime. I am not aware that shells and microscopic organisms contain any appreciable quantity. Hence it is clear, that in the case of Dolomites, there must have been in operation other causes than those dwelt upon in the preceding pages, which have separated the magnesia from the water, and precipitated it in an insoluble form. The chemical agents which would accomplish this, would produce the same effect on solutions of lime; and hence, as sea-water contains both, and there is every reason to believe that the magnesia was so thrown down, it almost renders it certain that lime has, in some cases, also been a chemical precipitate.

Another question closely allied to the preceding is,—From what source have the flints and cherts of Chalk and limestone been derived? It is well known that almost every calcareous deposit contains more or less of siliceous matter in some form or other, but most frequently aggregated either as nodules, or concretions, or horizontal layers. Ehrenberg remarks,—"In the south of Europe, the beds of marl which alternate with the Chalk, consist of siliceous shells of Infusoria, and flints

are wanting; while, in the North of Europe, beds of flint alternate with the Chalk, and marls with Infusoria are wanting. This exchange of character tends to explain the peculiar relation of flint to Chalk, indicating that the pulverulent siliceous particles of Infusoria have been converted into compact nodules of Flint."*

But there are reasons for believing that the great facts upon which this hypothesis is based, are incorrectly interpreted, and that no siliceous Infusoria belonging to the Cretaceous era have yet been discovered. The great siliceous deposits of Virginia belong unquestionably to the Miocene epoch. Those brought by Mr. Darwin from Patagonia, form part of a recent Tertiary deposit, and there is every probability that the Infusorial layers of Sicily and Northern Africa will ultimately be proved to belong to the Tertiary era. I am not aware that any observer has succeeded in verifying the alleged discovery of siliceous Infusoria in the English Chalk, and the American rocks which are unquestionably Cretaceous, have as yet been equally unproductive. If these facts be correct, of course the argument raised by

* Phil. Mag. Vol. xviii. p. 385.

Ehrenberg is done away with, so far as it is based upon the alleged absence of flint from Infusorial strata, and their presence where such Infusoria are wanting. At the same time, this does not prove that siliceous organisms *may not* have been separated from the calcareous elements of a rock, and subsequently brought together again in a new form, constituting flint. If anything of this kind has taken place, it could only have been by the introduction of some agent capable of dissolving the siliceous base of these structures, and any such agent would of course also act upon the siliceous sand grains, which occur more or less abundantly in every calcareous stratum; consequently, if the Flint has really been derived from the stratum itself, since sand grains are so much more abundantly diffused than Infusoria, or sponge spicula, even in the substance of the Flamborough sponges, it is more likely that the inorganic elements have been the usual source rather than the organic, though of course both would combine to produce the result.

It is, however, more probable, that the Silica has been derived from largely saturated hot springs, as advocated by Dr. Mantell in his "Notes on the Chalk and Flint of the south

east of England,"* and that whilst it has invested some objects, it has filled the cavities of others, and shewn a manifest preference for combining with, and replacing animal substances. This, however, is as yet a very obscure and difficult subject; one that must probably be treated very differently according to the strata we may be examining.

In some cases, as in the examples of silicified fossil woods, the flint appears to have been deposited atom by atom, since, though the carbon is replaced by silica, all the original microscopic structure appears to be preserved. At the same time, all the interstices and fissures in the wood are often filled up by clear chalcedony, which bears every appearance of having run into the fissures in a fluid state.

At other times the original elements of the organism have been wholly or partially removed, leaving a cavity, which has been filled up by infiltration of siliceous matter, subsequent probably to the consolidation of the rock; the interior of such organisms, when the filling up has not

* Annals and Mag. Nat. Hist. August, 1845.

been completed, exhibiting either a crystalline and quartzose, or the botryoidal aspect so common to the Chalcedonies deposited by the Geysers. In neither of these is any trace of the original structure of the shell preserved, and I cannot but think that the removal of the lime has in such cases been rendered more or less complete before the introduction of the silica; consequently, instead of being deposited in such a way as to preserve the original structure, atom replacing atom, the cavities are more or less perfectly filled with crystalline chalcedony, according apparently to the duration of the process, and the size of the cavity; the smaller organisms being in general completely solid, whilst the larger ones are merely lined with the siliceous matter. Similar phenomena occur amongst the silicified organisms of the harder portions of the Calcareous Grit in Yorkshire.

What has taken place in the flints of the Chalk? This is difficult to answer, as we have evidence of a much more complicated agency. I have already remarked, that the Rotaliæ from the chalky surfaces of flints, though unattached to the flint itself, are nevertheless often changed into silica, and it would appear that the Rotaliæ embedded in the solid flint have also become

silicified; but the silica replacing the calcareous cells has a more transparent aspect than that surrounding and filling them, as if the organism had been first silicified, and then invested with flint of a less transparent character. Moreover, some of these Rotaliæ clearly retain part of their original animal matter, apparently in the condition of Molluskite, as advocated by Dr. Mantell. I have already spoken of my instructive specimen from Flamborough Head. The outer calcareous part is silicified, its outline being comparatively distinct, as contrasted with the darker investing flint. The animal portion has shrunk up within the shell into a smaller compass, still preserving its original brown hue, and affording an almost exact representation, both as to colour and form, of the animal from the Levant (Fig. 29). In this case I can see no room for doubting that at least the colouring matter of the animal membrane is preserved; and, as in such a texture as this it would be difficult to divide the latter from the former, what ground is there for doubting that the animal membrane is itself present either in the state of Molluskite, or in such close and intimate union with the siliceous matter as to be justly regarded as a silicified animal? This is clearly no cast of the interior of the shell, filled up with a differently coloured flint

from that by which it is invested. The wide interval between the walls of each cell and the shrunken animal, which interval is occupied by transparent flint, like that outside the whole, seems to remove all possibility of doubt. The Levant specimen shews that the animal part of a Rotalia may be occasionally deprived of its calcareous covering, and yet be preserved, illustrating those instances which sometimes occur where this portion alone is found in a fossil state. If any number of living Foraminifera happened to have accumulated at a point where a volcanic spring charged with any solvent acid subsequently burst out, such results would be readily produced.

Some of the conclusions at which Ehrenberg arrived, resulting from his investigations into the composition of Chalk and Chalk marl, require to be received with great caution, as the facts upon which they are based are scarcely sufficient to support them. One of these is, that "many of the chalk-like formations bordering on the Mediterranean, in Sicily, Barbary, and Greece, really belong to the Chalk formation, as proved by their organic contents, although commonly held to be different from the Chalk, and considered as Ter-

tiary."* This conclusion appears to have been arrived at by Ehrenberg in consequence of finding certain organisms in them which occur in the Chalk; but the evidence afforded by the higher forms of Testacea and other animal remains, distinctly separates them. Now, a close investigation of the history of the Polythalamia, Diatomaceæ, and siliceous Infusoria, so-called, will bring us to the conclusion, that but little, if any, dependence can be placed on them, as a means of identifying either the age or the geological position of rocks. Beyond all doubt there exists in nature a number of minute structures, cosmopolites, which appear to be comparatively independent of the ordinary influences of locality and climate. The fresh-water pools of America, England, and Central Europe, contain not only identical forms of Desmideæ, Diatomaceæ, and Spongillæ, but there is a closeness of resemblance in the aggregation of their species which we do not usually observe in the distribution of the higher forms of plants or animals. Dr. Bailey has discovered few forms in the United States that have not also been found by Mr. Ralfs and his active coadjutors in England, whilst most of the leading species observed by the

* Phil. Mag. Vol. xviii. p. 385.

latter, have also been found by Ehrenberg in Central Europe.

If we turn to the ocean, we meet with corresponding results. Amongst the siliceous structures, the Actinocycli and Coscinodisci found in the stomachs of crabs from the west coast of Scotland, of muscles from Scarborough, and of Pectens from Brighton, occur equally in the waters of the Baltic, in the sediments of the Mediterranean, and in the guanos of Ichaboe, and Peru. Biddulphia pulchella has been found on our own coasts, in the Mediterranean, on the shores of Long Island U.S. at the Phillippine Islands, and at Cuba.

The Foraminifera bring us to analogous conclusions. Globigerina bulloides is found on both the coasts of America, at the Canary Islands, in the Mediterranean, and in the Indian Sea.* Bulimia elegantissima ranges from Patagonia to the coasts of Chili and Peru.† Four other species are common to Cape Horn and the Malvinas.‡ M. D'Orbigny adds, "when we unite together the

* Alcide D'Orbigny on the Foraminifera of America and the Canary Islands. Edin. New Phil. Journal. Vol. xxxii. p. 6.

† Idem, p. 11. ‡ Idem.

species of Arica and Callao, the harbour of Lima, that is from 12° to 15° S. lat., in order to compare them with those of 34° S., we have fourteen, of which four extend northwards as far as Paita and to the equator."* The same writer also tells us, that seven species of the Foraminifera, found at the Canaries, are also common to the southern and western coasts of France. One of them, the Truncatulina lobata, also occurs in the British seas and at the North Pole.

If, then, there is amongst these little creatures such an independence of climate and other outward conditions, the same thing would naturally influence their geological relations. They would survive catastrophes which were fatal to the higher organisms, and thus we might expect, *a priori*, to find individual species ranging through a number of strata, and during a comparatively long geological period, without affecting the great fundamental views which geologists hold as to the geological distribution and the periodic destruction of most living existences. Such is precisely what we have the authority of M. Ehrenberg himself for believing to occur;—

* Idem, p. 11.

Rotalia globulosa, R. turgida, Textillaria aciculata, and T. globulosa, the characteristic Foraminifera of the Chalk of England, having all been found living in the North Sea, at Cuxhaven. This alone is sufficient to show the impropriety of trusting to them as a means of identifying the age and geological position of any deposit.

The same line of argument applies equally to another of M. Ehrenberg's views. He says,—"The idea that the temperature and constitution of the atmosphere and ocean were essentially different at the period of the Chalk formation, and adverse to the organized beings at present existing, naturally acquired more probability and weight, the more decidedly different all the creatures of that period are from those of the present time; but loses more and more in importance, the less Chalk proves to be a chemical precipitate, and the more numerous the forms, agreeing with those of the present day, become by renewed enquiry. Nay, there is not the least doubt that the perfectly ascertained identity of a single species of the present day, with one of those of the Chalk, renders doubtful the necessary transformation of all the others, subsequently to the formation of the

Chalk rocks. How much more so when these are numerous, and such as form large masses. The size appears to be of no importance, as the small organisms have already been shewn to agree with the large, with regard to the effect of external influences upon them."*

As regards the higher animals, the first part of this paragraph is doubtless correct; but the force of the argument is weakened, if not destroyed, when it is applied to the Foraminifera and other microscopic creatures. The small organisms do *not* agree with the large, with regard to the effect of external influences upon them. With reference to climate, enough has been said to prove, that they neither follow parallels of latitude, nor isothermal lines; and as regards another condition, Professor Forbes has shewn that Foraminifera occur in the sea, at a depth of one hundred fathoms, when the higher forms of animals and plants cease to exist;† also, Alcide D'Orbigny informs us, that, opposite Cape Horn, at a depth of one hundred and sixty metres, (about eighty-seven fathoms,) the

* Edin. New Phil. Journal. Vol. xxxiv. p. 258.

† On the Light thrown on Geology by Sub-marine Researches. Edin. New Phil. Journal. Vol. xxxvi. p. 319.

bottom of the sea only furnished an abundance of Foraminifera. These facts indicate important differences in the effect of external influences, and at least show that the evidence afforded by the Foraminifera, must not be allowed to outweigh that furnished by the higher plants and animals, which are so much more sensitive to changes of latitude, climate, and depths of ocean. This is all consistent with what we know of the low sensibility of even those higher forms of Infusorial animals, such as the Rotifera, which, Dr. Carpenter tells us, may be frozen up in ice and thawed again for a succession of times without life being destroyed. The Foraminifera, it must be remembered, have a much less complicated organization, and hold a lower position in the scale of animal life than the Rotifera, and, consequently, might be expected to be still less under the influence of external agents.

More recently M. Ehrenberg appears to have altered his opinion on some of these points. In a recent work* he remarks, "As a considerable number of the species of animals belonging to the

* Verbreitung und. Einfluss des Mikroskopischen Lebens in Sud und Nord America.

Chalk formation of Sicily still exist, and, consequently, cannot be wanting in the Tertiary formations, it is evident that no conclusion, as to the geological age of these formations, can be drawn from the similarity or dissimilarity of these forms."*

This paragraph annuls much of M. Ehrenberg's previous argument; but as the latter has been far more widely circulated in England than the former, it is desirable that every opportunity of correcting the error should be made available for that purpose, and more especially as M. D'Orbigny still appears to hold some similar views, notwithstanding the numerous opposing facts which he has himself brought to light.† Speaking of the study of the Foraminifera, as applied to geology, he remarks, that "as these minute shells are infinitely more common than those of molluscs, the knowledge to be derived from them is so much the more certain, and becomes extremely interesting." And again, after stating his opinion, that different terrestrial zones have their peculiar species, he

* Silliman's American Journal of Science. Vol. xlvi. p. 297.

† Mr. Weaver's Abstract of the Memoir of M. Alcide D'Orbigny, on the Foraminifera of the White Chalk of the Paris Basin. Phil. Mag. Vol. xviii. p. 456.

adds, " Hence, the geographical distribution of living genera and species offers to us a means of comparison of the highest importance, with a view to the determination of the temperature of the waters in which the fossil species lived, and may lead to very satisfactory results in geology, if we may judge by the fruits of our observations in this respect."*

These conclusions require to be received with the utmost caution, if the study of the Foraminifera is to be made of any real use in the attainment of new geological truths. Our knowledge of these singular creatures is as yet much too elementary, for us to come with safety to any very general conclusions. M. D'Orbigny's paper, from which the above is quoted, is an evidence of this. After advancing various arguments to prove that the temperature of the great basin in which the Chalk of Europe was deposited, was analogous to that of the Adriatic at the present time, he adds, " To complete the approximation, it (the Adriatic) exhibits to us the only two living species, the analogues of which are found in the fossil state in the white Chalk, viz. Denta-

* See preceding Note. Mr. Weaver's Abstract, p. 457.

lina communis, and Rotalina umbilicata."* The same volume which contains this remark, also contains the opposing observation of M. Ehrenberg,—that, of the Foraminifera found in the white Chalk, *nine* still exist, of which *six* occur *in the North Sea, at Cuxhaven;* four of the six being found in the white Chalk of England, which M. D'Orbigny distinctly includes in his supposed analogy to the Adriatic. On seeking for the analogues of the beautiful little fossils from the Charing chalk, I found examples of either several of the species, or of others exhibiting the closest resemblance to them, in the cabinet of Mr. Bean, at Scarborough, who chiefly obtained them from various localities on the Scotch coast. At the same time, many recent and fossil species bear so close an external resemblance to each other, that it is a most difficult thing to decide with absolute certainty which are and which are not distinct. Some of our best observers in England doubt, for instance, the identity of M. D'Orbigny's Dentalina from the Chalk and the recent D. communis; yet this is one of the species upon which that most acute observer builds his hypothesis.

* Idem. p. 462.

How cautious must we then be in advancing any conclusions relating to temperature and climate, as well as to the geological age of rocks from such comparatively uncertain data. To use the language of a distinguished writer, in his well-merited criticism of a very different work from any of these which have rendered so illustrious the names of Ehrenberg and D'Orbigny, "We may explain the obscure cases of nature's work by appealing to the clear—but do not let us stultify what is clear, by starting with the obscure."* So, in like manner, we must not cloud the evidence afforded by the higher animals, with that derivable from beings so much lower in the scale of organization, and which, as a whole, are so far removed from the influence of external agencies. The study is at once so novel and so fascinating, that all who pursue it, impressed by its singular interest, are in danger of being allured by it beyond the bounds of caution,—a tendency which is ever promoted by the announcement of comprehensive hypotheses and splendid novelties.

* Review of the Vestiges of the Natural History of Creation. Edin. Review, No. 165, p. 65.

I cannot close this memoir, without once more drawing the attention of the Society to the important part which the minute and singular beings now brought under our notice, play in the economy of the physical world. If we look into the ditches and pools of our immediate neighbourhood, we find them teeming with some form or other of these microscopic structures. The superficial mud of our rivers, lakes, and estuaries, is alike vital with their swarming millions. The waves of the ocean, when glittering with phosphorescent splendour, indicate that, however pure and transparent they may appear to the unassisted vision, they are loaded with similar forms of organic life. From the stormy seas of the Northern Pole to the wild and desolate shores of Mount Erebus,* these atoms of creation exist in all their variety of structure, and wondrous diversity of movement. They form some of the earliest instruments by which inorganic elements are transmuted into an organized condition. They constitute the pabulum of myriads of those bulkier creatures which, though of so much more apparent importance, could be better spared without deranging

* Ehrenberg, on Microscopic Life in the Ocean at the S. Pole. Annals Nat. Hist. No. 90, p. 169.

the physical economy of the world. Abounding at almost every point, they act as nature's universal scavengers, taking up those decomposing substances which would otherwise fill our waters with impurity, and our atmosphere with the elements of disease.

Our feeling of wonder, however, reaches its climax when we are informed that even many of "the everlasting hills" owe their origin to such pigmy architects of nature; enduring monuments of the mighty results that may ensue, from the long-continued action of causes the most minute and inappreciable. It is gratifying to find so clearly written in this, one of the last opened pages of nature's volume, a truth which in the moral world, is everywhere proclaimed; a truth that should inspire the mind, not only with wonder, but with humility and adoration.

2.—*On the Times of Occurrence of the Daily Atmospheric and Barometric Disturbances at Bombay.* By Thomas Hopkins. Esq.

(Read, November 17, 1846.)

That the daily fluctuations of the barometer in many parts of the world are connected with the changes of winds called sea and land breezes, is generally admitted. Some persons consides the winds the causes of the barometric alterations, whilst others treat the phenomena as joint effects resulting from the same common cause; these winds, however, have seldom been examined with a view of showing to what extent they coincided with the movements of the barometer. But it is desirable that this should be done, as any anomalies in the daily movements of the barometer, and in the times when the sea and land breezes blow, may direct attention to causes which, without having been noticed, may, to a greater or less extent, determine each of these phenomena.

A sufficient number of facts has been collected to enable us to show, that the sea and land breezes do not blow at the times when it would be expected that they should, through alterations that are taking place in the atmosphere, as such alterations are indicated by the movements of the barometer. These breezes are said to blow invariably from a part where the atmosphere is relatively heavy, to another part where it is lighter; we ought, therefore, to find, that wherever the sea breeze was blowing with increasing strength, the atmosphere on the land towards which it was blowing, was becoming lighter, and the barometer on the land was falling. In like manner when the land wind was blowing with increasing force, the atmosphere must be supposed to be increasing in weight over the land, which increase should be measured by a rise of the barometer on the land.

If, however, the movements of the barometer do not accord with the times of these winds, but that instrument sometimes rises when from the direction of the wind, it should fall, and the reverse,—we have to ask why this should occur? There must be some sufficient cause in operation to produce these effects, so different from what is expected from the nature of the influences sup-

posed to produce them, and into the nature of this cause we ought to enquire.

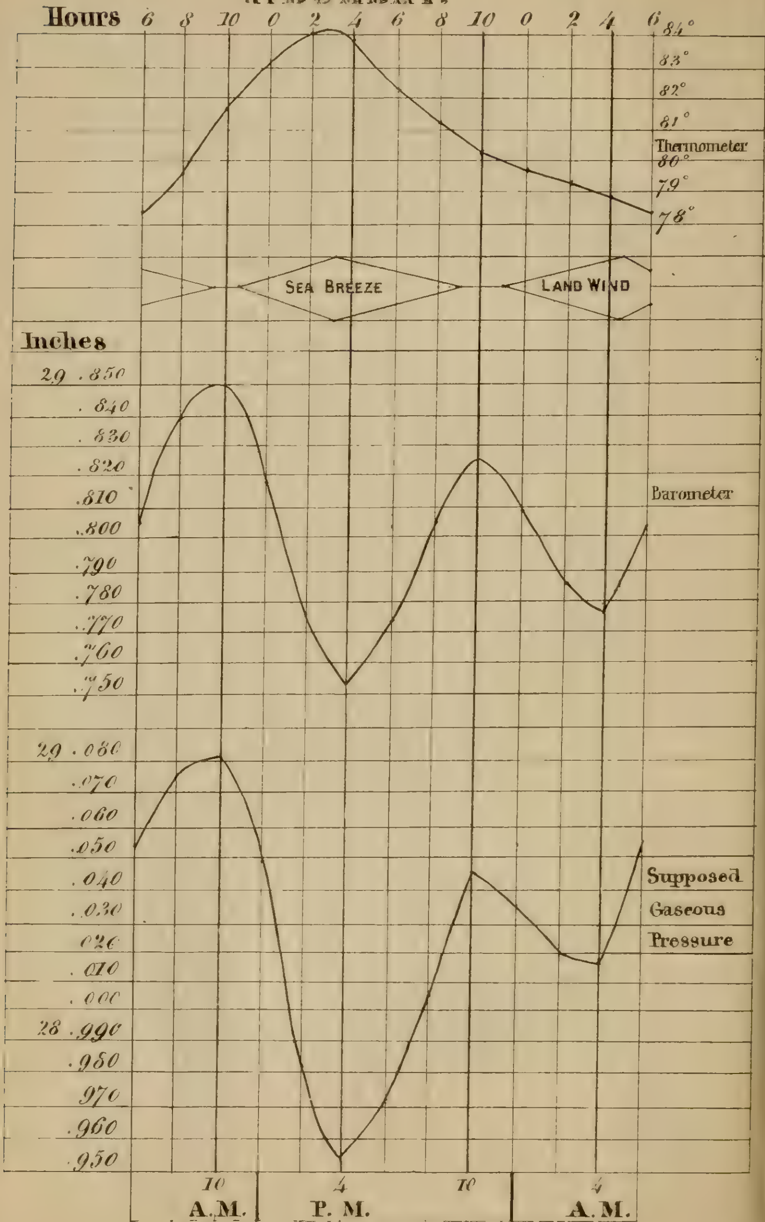
The combined influence of temperature, as shewn by the thermometer, and of variable vapour pressure, as ascertained by the dew point, have been supposed sufficient to account for both the daily changes of the wind and of the barometer. But I have shewn, in a paper published in the "Philosophical Magazine" for December, 1845, that the dew point is not a correct measure of the quantities of aqueous matter that exist in the atmosphere during the different periods of the day; although there can be no doubt that those quantities do vary, and, in many parts of the world, probably to a greater extent than has been hitherto imagined, though the aqueous matter is not always in the form of vapour.

Alternating sea and land breezes are, doubtless, effects of the disturbance of the equilibrium of atmospheric pressure. The air passes from the place where the pressure is greater towards the part where it is less, and this passage of the air constitutes the wind. In the important account of the Meteorology of Bombay, furnished to the British Association at Cambridge, by Colonel

Sabine, it is stated, that "the land wind declines till about ten o'clock a.m. at which time the direction of the aerial current changes, and there is generally a lull of an hour, or an hour and a half's duration. The sea breeze then sets in, the ripple on the surface of the water indicating its commencement, being first observed close in shore, and extending itself gradually out to sea. The sea breeze is freshest from two to four, and progressively declines in the evening hours."

According to this, as well as other accounts which need not at present be given, we may then say, that soon after ten o'clock in the morning, some cause comes into operation that makes atmospheric pressure less over the land, than it is over the sea, and therefore a portion of the air flows from the sea to the land,—from where the pressure is greater to where it is less. This disturbance of the equilibrium of atmospheric pressure has been represented as arising from the sun heating the surface of the land more than that of the sea. But if this were the cause in the case just given, the sea breeze ought to have set in earlier, seeing that the thermometer at Bombay, near the surface of the earth, rose much more before half-past ten o'clock in the morning, than it did after that time.

DIAGRAM
of the Semi-diurnal alterations of the
THERMOMETER, WIND, BAROMETER, & SUPPOSED GASEOUS PRESSURE,
AT BOMBAY.



From six in the morning the temperature rose from 78°.4 until at ten it reached 81°.8, and at twelve 83°.2. So that at ten it had risen 3°.4, and at twelve 4°.8, whilst after that period until two it rose only .9 or to 84°.1. The rise of temperature was therefore at least twice as much before the sea breeze set in at half-past ten as it was afterwards, and the sea breeze ought to have commenced long before half-past ten o'clock to have been in accordance with the times of the change of temperature. The following table taken from Colonel Sabine's paper, shows the heights of the thermometer and the barometer, and the supposed separate gaseous pressure every two hours. The same facts are also exhibited in the opposite diagram, together with the changes of winds :—

Hours of mean, Bombay time.	Thermometer.	Barometer.	Supposed Gaseous Pressure.
6	78°·4	29·805	29·055
8	79°·6	—·840	29·074
10	81°·8	—·852	29·081
0	83°·2	—·817	29·049
2	84°·1	—·776	28·981
4	83°·9	—·755	28·955
6	82°·3	—·774	28·972
8	81°·2	—·806	29·005
10	80°·3	—·825	29·045
0	79°·8	—·809	29·034
2	79°·4	—·786	29·020
4	78°·9	—·778	29·017

The highest temperature 84°.1 is found at two o'clock, after which time it declines a little till four when it is at 83°.9 ;—and if high temperature, as measured by the thermometer, really produced the sea breeze, it should have increased in strength until two, when as the temperature declined, the breeze should also decline. But the sea breeze is found the strongest from two to four o'clock. The sea breeze, therefore, is of inferior strength up to two o'clock, when it ought to be the strongest, and it is the strongest when it should, according to the temperature theory have been for two hours becoming weaker.

At four, although the atmosphere, as shown by the thermometer had become colder than it was at two o'clock by .2, yet it was then in its lightest state, as measured by the barometer, showing that the temperature and weight of the atmosphere were not in harmony with each other. After four the barometer begins to rise, and the sea breeze to weaken, and these alterations proceed until near ten at night, when they cease.

At this time the air over the land as measured by the barometer, is found to be heavier than that over the sea, and the aerial current turns and

begins to flow from the land to the sea,—or the land breeze sets in. It is feeble at first, but increases in strength until it reaches its maximum near day break, say between four and five o'clock, during which time the temperature declines. While, however, the land breeze is thus blowing with increasing strength, and indicating by its force that the atmosphere is becoming considerably heavier over the land, the barometer, which should be the measure of increase of atmospheric weight, does not rise as from theory would be confidently expected, but actually falls! And that this fall of the barometer is not attributable to a rise of thermometric temperature, as that of the morning has been supposed to have been, is evident, because the thermometer was sinking during the whole time. That the fall of the barometer is not due, to a general reduction of atmospheric pressure may also be reasonably inferred, seeing that the land breeze indicates an increase of that pressure over the land, from whence the air is by some cause forced to flow towards the sea. What then can make the air go with increasing velocity from a part where the atmospheric pressure, as that pressure is measured by the barometer, is successively becoming less and less? Or rather, we may ask, what can cause

this fall of the barometer on the land, when, from the action of the land wind, the air over the land appears to be increasing in weight? These questions, it would seem, cannot be satisfactorily answered on the temperature theory, and yet they require to be answered, if we are to understand the causes that are in operation to produce the various results that have been traced.

From what has been stated, it will have been seen that after ten o'clock in the morning, some cause comes into action, sufficiently powerful to reduce atmospheric pressure on the land, and to render the air there so light as to permit the sea air to flow towards the land as the sea breeze. This cause, I contend, is not to be found in the warming of the surface of the land by the sun, as has been supposed,—but in the conversion of a part of the aqueous vapour of the atmosphere into water by the formation of cloud, as I have shown in my account of the formation of the cumulous cloud. A consequence of this conversion is the liberation of heat, which lightens the whole atmospheric column in the locality. The results are, a fall of the barometer over the land, and a flowing in of the heavier air from the sea as the sea breeze. The formation of cloud, on

an average, continues in operation until four o'clock in the afternoon, during the whole of which time the barometer falls, and the sea breeze blows with increasing force. At four o'clock cloud ceases to form,—the barometer then ceases to fall, and soon begins to rise, whilst the sea breeze becomes weaker, until about ten o'clock in the evening, when the barometer attains its greatest evening height, and the sea breeze ceases to blow.

During the six hours last named, from four to ten o'clock, that the atmosphere over the land becomes heavier than it had previously been, is indicated both by the rise of the barometer and the decline of the sea breeze. But it is here contended that these results are produced, not merely through that reduction of temperature which is marked by the fall of the thermometer, but in addition, and principally, through the cooling of a large mass of the atmosphere by cloud evaporation. From ten in the morning to four in the afternoon, a portion of the vapour over the land had been condensed and formed into cloud; and the heat liberated by that condensation rendered the land atmosphere lighter at the time: but now, from four to ten at night,

the particles of water which constitute the cloud evaporate—and as condensation previously heated the land atmosphere, and made it lighter, so evaporation now cools it and makes it heavier. The former process caused the barometer to sink, and the sea breeze to blow—the latter causes the barometer to rise, first checks, and finally stops the sea breeze. Cloud formation in the former period produced so great an effect as to counteract the influence of increasing vapour pressure, which may be shewn to have existed at the time, and in addition to lower the barometer and produce the sea breeze; and cloud evaporation had, in the latter period, sufficient power to overcome the influence of declining vapour pressure, which was going on at the time in the formation of dew near the surface, and to produce the general results that have been stated.

At ten at night, the air over the land is found to be, principally, through the influence of cloud evaporation in cooling the column, heavier than it is over the sea—the atmospheric current once more turns, and the air begins to flow from the land to the sea—or the land breeze sets in. It is feeble at first, but increases in strength, until at day break, or about four or five o'clock it

reaches its maximum. While, however, the land breeze is thus blowing from eleven at night to four in the morning, and seeming to indicate that the air is becoming heavier over the land, the barometer on the land at Bombay is not rising, as might be expected, but on the contrary is falling. Now that this fall is not attributable to an increase of temperature is clear, as during the time the thermometer is sinking! And that it is not due to a general diminution of atmospheric pressure is to be presumed, because the land breeze shows that that pressure is increasing over the land! What, then, is the cause of this fall of the barometer? It is, apparently, the reduction, not of general atmospheric pressure, but of separate vapour pressure through the deposition of dew.

From ten at night to five in the morning, the period now under consideration, radiation of heat cools the surface of the earth, and that part of the atmosphere which is near to it, sufficiently to condense a part of its vapour, without thereby raising the temperature, as the cooling effect of radiation is greater than the heating influence of condensation of vapour, and the results are the deposition of dew and the reduction of vapour

pressure without an increase of temperature. It is, then, the reduced pressure of vapour, and not any diminution of gaseous pressure which we presume causes the barometer to fall during the time last named. The land wind blows at the same time; because in the absence of the sun the gaseous part of the atmosphere continues to cool over the land, and the land gases press on the lighter sea gases, and flow from the land towards the sea, constituting the land wind, which increases in strength with the cooling of the gases over the land up to about sunrise.

Here, then, we see why—when, from the increasing strength of the land wind, we should expect that the barometer would rise—it falls! We see that the fall of that instrument is a consequence of reduced vapour pressure alone, whilst the reduction of that pressure does not prevent the colder gases over the land from flowing as a land wind towards the sea, where the atmospheric gases are warmer.

The approach of the morning sun prevents further cooling, and his rise soon begins to warm the atmosphere; the land breeze then diminishes in strength, until about ten o'clock when it ceases.

But from five to ten in the morning, whilst the land breeze is declining through an increase of general temperature, and a consequent reduction of gaseous pressure over the land, the barometer is not sinking, as might be expected, but it is, on the contrary, rising. Whence, then, comes the force that now raises the barometer? It is from the increased pressure of the additional vapour which, during this time, is produced by evaporation from the surface of the earth. As the temperature rises in the morning, evaporation becomes more active, and additional vapour is thrown into the atmospheric space, which adds to the vapour pressure. Thus, while one constituent of the atmosphere in the locality is increasing in quantity, and adding to the aggregate pressure, other constituent portions, through a rise of temperature, are pressing with diminished force on the surface, exhibiting to us at the same time the apparent contradiction of a rising barometer, and an alteration of wind that shows a diminishing atmospheric pressure. These phenomena are, however, the natural results of the independent action of the different aeriform substances that constitute the atmosphere.

Each of these constituents exists in the atmo-

spheric space, as an independent elastic fluid, the upper part of which presses on the lower, the weight of the whole resting on the surface of the globe. When aqueous vapour, one of these, is increased in quantity by evaporation, its weight is increased, and the whole of the vapour presses on the surface with greater force: and a column of mercury exposed to this pressure rises to an extent that is proportioned to the increase in the weight of vapour. But at the same time that this is going on, the gases, the other constituents of the atmosphere, may become warmer and lighter in the part. And it is this lightening of the gases in the morning, that first reduces the strength of the land wind, and finally stops it, whilst the barometer is rising from an increase of vapour pressure.

The independent actions of the constituents of the atmosphere from four to ten in the afternoon, though the same in their nature as those in the morning, are differently combined. During this time, cloud evaporation over the land cools the gases, and makes them heavier, and vapour pressure is increased by cloud evaporation, whilst the small condensation of aqueous vapour that is taking place near the surface in the formation of

dew, is tending to make the atmosphere lighter, but the two former are the more powerful influences, and the barometer rises. Yet, while this rise is going on, the sea breeze is declining, because the cooling of the gases is making them heavier over the land. But after ten at night, cold ceases to be produced by cloud evaporation, and no more vapour is furnished by that process, whilst the reduction of vapour pressure by the deposition of dew continues. The reduction of vapour pressure has now superior influence on the barometer, and it falls from ten in the evening to four in the morning, although, during this time, the gaseous atmosphere must be becoming heavier, from the decline of temperature. The influence of the cooler, and therefore heavier, land gases, is seen in the increasing force of the land wind, which, up to four or five o'clock, becomes successively stronger, while the barometer is falling.

It may be further observed, that the gaseous atmosphere, is, in the temperature theory, supposed to be at its mean pressure at Bombay, about one o'clock in the day, as that is the time when the barometer is at its mean elevation, and, therefore, when the atmosphere in the locality ought to be in a state of equilibrium, and at rest;

but instead of being at rest, the sea breeze is then found blowing freely, and with increasing strength. At about four in the morning the gaseous pressure is represented as being again at the mean, but at both these times wind is blowing. Now if the theory were correct, from which separate gaseous pressure is deduced, we should have a calm, when the pressure was at the mean; whereas, at the times which have been pointed out, of the computed mean, decided winds were blowing.

And when the air at ten in the morning is found calm, we ought to presume, from the existence of that fact, that an equilibrium of gaseous pressure is established, such equilibrium being the necessary accompaniment of a calm. But the separate gaseous pressure, as that pressure is deduced from the dew-point is very much above the mean, seeing that it is at the highest that it attains in the twenty-four hours.

In like manner, at ten o'clock at night, when the gases are at rest, and when therefore they must be supposed to be under the influence of a mean pressure,—the amount of that pressure as deduced from the theory, though not so great as

it was in the morning,—is represented as being much above the mean. These facts present strong evidence that the method of ascertaining the separate gaseous pressure at present recognized cannot be a correct one.

We have already seen reason to believe that the barometer attains its greatest height in the morning through increased vapour pressure. And it is to be presumed from the stillness of the air at the time, that the gases were then really in a state of equilibrium; it will, therefore follow, that at ten in the morning, the barometer was raised above its mean height, solely by the force of increased vapour pressure. And at night, there is another calm, when the barometric height is considerable, approaching that of the morning, and this pressure above the mean must in like manner be presumed to result, not solely from the cooling of the atmosphere, but in addition from the abundant vapour that had been recently furnished by cloud evaporation. The general conclusion to be drawn from all these facts, being, that when the atmosphere is in a state of equilibrium, any rise of the barometer above the mean level for the locality, climate, and season must be produced by increased vapour pressure.

Thus we find, that we have only to trace the effects of the various changes of temperature, arising from the different causes that are known to be in operation on the separate constituents of the atmosphere, to perceive with considerable clearness, how all those alterations in atmospheric pressure, and changes of wind, which appear at the first view so incompatible and contradictory, are accomplished. The constituents of the atmosphere, separately, and independently, obey the laws which govern them, and although in so doing, they may impinge upon, and to some small extent disturb each other in their movements, yet the daily fluctuations of temperature, which are the primary disturbing causes, are sufficiently slow to allow each elastic fluid to act nearly in conformity with its own laws. When vapour is, by the slow process of evaporation, discharged into the atmosphere, it penetrates the atmospheric mass, ascends, and also expands laterally, yet rests on the surface of the globe with its own weight alone, that weight being increased or diminished as the vapour becomes more or less in quantity. But, in spreading laterally, the vapour has not sufficient force to impinge upon, and carry along the gases,—it therefore does not, in a direct and mechanical way, produce a wind.

Variations in the temperature of the gases, however those variations may be produced, are the great causes of winds, both irregular and periodical; and these variations may be combined with an increase or a decrease of vapour, in such ways as shall create atmospheric currents, and at the same time affect the barometer in such different modes, as to produce all those various and complicated phenomena, that have, hitherto, baffled enquirers on the subject.

III.—*On the Origin of Coal.* By E. W. Binney, Esq.

(Read December 1, 1846.)

The vegetable origin of Coal is now fully established, and the problems remaining to be solved are the following, namely, where did the plants of which Coal is formed grow? and how were the strata in which it is found deposited?

Some years since Sir H. T. De La Beche, in his Researches in Physical Geology, first alluded to the great value of fossil organic remains, especially those of such animals as formerly lived in the ocean, in ascertaining the depth of the ancient seas at the period when such beings existed, and he gives a table of the depths at which some recent shells are met with on the coasts of England. Professor Edward Forbes, in his report of the dredging of the Ægean sea, supplied geologists with a mass of most valuable information as to the habitats of recent shells, and in a paper read by himself and Captain

Ibbotson, on the Tertiary and Cretaceous deposits of the Isle of Wight, at the meeting of the British Association, at York, in 1844, showed how it should be applied in measuring the depths of the ancient seas.

The level of the ocean itself is now assumed by geologists to have been permanent, whatever variations may have taken place in its bottom.

In the present communication it is the author's desire to direct attention to the constant evidence of subsidences in the bed of the ancient ocean, from the commencement of the protozoic rocks, up to and including the new red sandstone formation on the western side of the *penine* chain, and to point out some of the great epochs of repose which have at intervals of time, in particular places, for a period interrupted such subsidences. Every group of fossiliferous strata offers numerous evidences of subsidence interrupted by periods of rest, but the periods of elevation are not so observable, although it is probable that they must have acted on other parts of the earth's surface to counterbalance such subsidences. But geological works have lately been published wherein the earth's crust is not only assumed to

have frequently subsided, but to have been again elevated, so as to account for the occurrence of successive seams of Coal, an elevation and a subsidence being necessary for the formation of each seam.* This is a very unlikely hypothesis, when the degradation of pre-existing rocks, and the conveyance of them, by the action of running water, is so evident in all the deposits ; a subsidence of the bed of the present shallow seas would not necessarily require the assistance of any subterranean force to regain its former level, if we allow the action of currents of water charged with sand and silt.

The crust of the globe furnishes us with numerous evidences of the ancient ocean, but the direct evidences of absolutely dry land before the commencement of the Tertiary period are very few. The only instances in England that I am aware of are some in the new red sand stone formation, hereinafter alluded to, and the Portland dirt bed,—and the latter may have been more of a swamp than absolutely dry land. No doubt the existence of tracts of dry land in many of these remote ages, as assumed by some

* Dr. Mantell's Medals of Creation. Vol. i. p. 98.

geologists, and sanctioned by the remains of the Cheirotherium, some insects, the Stonesfield slate, and other animals, is very probable; but positive evidences in support of it, have not to my knowledge been hitherto adduced. At the present time the whole of the dry land upon the face of the globe could be covered by the waters, and a universal sea of considerable depth exist. Great mountain ranges, such as the Himmylaya and the Andes, could easily be buried in the depths of oceans like the Pacific and Atlantic. This is mentioned for the purpose of shewing that it is not necessary to assume the existence of perfectly dry land, in order to account for such seas as those in which most of the beings whose remains we find embedded in the older rocks lived.

The lowest slates of North Wales seem to indicate a sea of considerable depth, the sedimentary deposits at the bottom of which were often disturbed by admixture of volcanic matter in the shape of trappean rocks. It is a difficult matter to state when the first evidence of animal life appeared in the waters of the ancient sea, but there is proof that it existed near Arenig Fawr, where the Asaphus *Buchii* and a few other fossils

occur.* The injection of volcanic trap into the sea at some places, no doubt frequently interrupted and destroyed the inhabitants of its waters, but these disturbances being only local would not interfere with the creatures living in distant seas; so that although certain races were partially cut off at particular periods, in some localities, other places existed where the same races of animals escaped destruction, and re-peopled the seas, when such again became fitted for animal life.

The ancient seas, like those of the present day, were doubtless peopled with beings fitted for the conditions under which they lived, and when such conditions changed the animals changed accordingly. Some of these changes were no doubt sudden, and others gradual.

A great irruption of trappean rocks into the sea, the rapid subsidence of its bottom to a great depth, or the elevation of the bottom of the ocean to the surface of the water, would be all equally fatal to animal life in the respective

* See Professor Sedgwick on North Wales. Quarterly Journal of the Geological Society, No. I. p. 8.

localities, where such changes took place; but the cessation of volcanic agency in the first case, the partial filling up of the bed of the ocean in the second, or the subsidence of the surface of the earth in the last, would again fit them for animal life. Again and again the subsidences of the bed of the ocean appear to have taken place, during the formation of the Silurian groups, as the successive bands of fossiliferous rocks testify. Some of these being of great extent, would cause the depth of the waters to be so great as to render them unfitted for animal life; whilst others might for a period be so gradual as to permit the animals to adapt themselves to the altered conditions, or build their way up against the subsiding rocks, like the Zoophytes of the present coral reefs.

At the close of the Silurian system in North Wales, an elevation or a period of repose, it is difficult to say which, of the strata appears to have taken place, as few, if any traces of the old red sandstone are said to be met with in the north eastern counties of Wales; but in the south east of the principality, that deposit is found of great thickness, gradually passing into the underlying Silurian group, thus showing that the subsidence in the latter district was going on

during the elevation or period of rest of the former. The whole of its materials, and the few organic remains found in its fossils, as well as the sand of which it is composed, show that it was not deposited in a deep ocean, as these are seldom met with at great depths in our present seas. The grains of sand also indicate considerable currents, which we should not generally expect to find in very deep water. The thickness of this formation is very great, reaching, according to Murchison, (p. 184 of his Silurian System,) to nine or ten thousand feet; a depth of sea which the composition of the rocks and the organic remains found in them, seems to render it next to impossible, but that subsidences of its bottom frequently took place during its formation. From the conformability of the rocks in some positions, it is now generally admitted that the old red sandstone in some places passes upwards into the mountain limestone, as at Stockpole Cliffs, (p. 383 Murchison's Silurian System,) and many other localities. However, in the north east of Wales, this transition is not to be observed, but the mountain limestone reposes on unconformable Silurian rocks.

The mountain limestone, or, as it is now

generally termed, the carboniferous limestone, may be considered as the base of the profitable Coal-fields of the north of England. Professor Phillips in his treatise on the deposit in Yorkshire, divides it into two parts, namely, the lower limestones and shales, and the Yoredale rocks or limestone shale. Each of these divisions at the greatest points of development reaching to near one thousand feet. The thickness of the lower limestone in Flintshire, I have not been able to ascertain, but the limestone shale in that county does not appear (if at all) to anything like the extent which we find it in Yorkshire and Derbyshire. The organic remains in both deposits, consisting of corals and shells, lead us to suppose that the creatures which belonged to them lived in seas of moderate depth; and that the beds of those seas were gradually subsiding, so as to compensate for their filling up by the deposition of carbonate of lime, sands, and argillaceous beds, brought thither by the water.

Having thus hastily glanced at the deposits on the crust of the globe, which were found prior to the millstone grit, and shown the evidences of continued subsidence in some portions of it compensated for, by continuous sedimentary deposits,

let us examine the great Coal-field of Lancashire, now admitted to be the most perfectly developed one in England. Before doing so, however, allow me to direct attention to the errors which have been generally propagated, with regard to carboniferous deposits, by describing nearly all of them as Coal basins. Doubtless, synclinal axes are to be met with in Coal-fields as elsewhere, but not more frequently than in any other equally ancient deposits. The great lines of fault by which Coal-fields are traversed, have all been formed after the deposition of their highest members. But it has been common to suppose a deep basin-shaped hollow in the crust of the earth, of near eight thousand feet deep, having a permanent bottom, which has been gradually filled up by the deposition of limestone, and the *detritus* of ancient lands, occasionally varied by drifts of vegetable matter, so as to form Coal seams. The fossil organic remains, both in the limestones and Coal measures, on being examined, clearly negative any supposition that when alive, the creatures which belonged to them ever lived but at moderate depths; therefore, all the advocates of the different hypotheses of the present day, whether they attribute the origin of Coal to vegetable matter, drifted from adjoining lands;

vegetable matter, which grew on dry land, on the spots where it is now found; or those who merely contend that such vegetable matter grew on the spots where it is now found, without stating whether it grew on dry land or in water must admit of the existence of a subsiding area in their different views.

Different opinions have been held, as to whether the waters which formerly prevailed, during the deposition of the higher part of the carboniferous series were fresh or salt. The authors who take the former view, adduce in support of their hypothesis the remains of a Cypris, and a questionable species or two of Unio; whilst those of the latter adduce shells of the genera, Goniatites, Nautilus, Posidonia, Pecten, Modiola, and Nucula, the great Sauroid and Squaloid fishes, as well as those of the Platysomus, Cælacanthus, Palæoniscus, &c. genera common to the carboniferous, and the magnesian limestone formations. Whether the strata contain the remains of fishes, Pecten, Goniatites or Unio, the remains of such plants as the Sigillaria and its Stigmaria roots are equally present; which would not be expected to be the case if sudden changes of the waters, from fresh to salt, had taken place; for a *Flora* is

quite as sensitive of such a change as a *Fauna*. The balance of evidence, therefore, is much in favour of the water having been of *one kind*, and on the whole, probably salt and not fresh.

The materials composing the various beds, known by the term Coal measures, are the main characters that will enable us to judge of the circumstances under which they were deposited. These are to be regarded as true measures of the intensity of the currents of water, which brought them to the places where they are now found, and are, therefore, of great value in ascertaining the physical condition of the globe at that period. They may be conveniently divided into arenaceous and argillaceous beds.* The first, consisting of rough pebbly gritstone, gritstone, fine sandstone, and sandy shale. The last, of shale, bind, soapstone, fire clay, and indurated silt. Black bass is also an argillaceous deposit, mixed with a considerable proportion of bituminous matter. Probably these deposits may not always occur in the exact order here pointed out, or all of them together; still, in the rich part of a Coal-field they graduate one into another with great

* Beds of limestone are met with in the upper Coal-field, but they are very rare.

regularity, and Coal is found on the deposit showing the greatest quietude of formation, which is nearly in all cases the floor.

Little evidence is at present to be had of the power of moving water, to remove bodies immersed in it, or which obstruct its progress, and further experiments require to be made. In vol. 49, No. I, p. 2, of Professor Silliman's American Journal, Mr. Mather, in a paper on the physical geology of the United States, gives the following table of the transporting power of water:—

POWER OF TRANSPORT.	VELOCITY OF CURRENTS.	
	In. per sec.	Miles per hour.
Wears away fine compact tough clay...	3	0·17
Removes fine sand........................	6	0·34
Sand as coarse as flax seed.	8	0·45
Fine gravel....	12	0·68
Pebbles of an inch in diameter...	24	1·36
Angular fragments, 2 to 3 inches	36	2·14

This last indicates a current, sufficient to move the largest pebbles found in the rough rock, one of the coarsest grained beds of the Coal measures.

Being best acquainted with the Lancashire and Cheshire Coal-field, it may be as well to mention

the thickness of its various beds, commencing with the lowest millstone grit and terminating (as far as yet ascertained) by the red clays of Ardwick near Manchester. It is full six thousand six hundred feet in thickness, and contains at least one hundred and twenty different seams of Coal. In a former paper, read before the British Association at Manchester,* it was divided into lower, middle, and higher. This division will be adhered to in the present instance, merely giving the workable seams.

	SEAMS.	THICKNESS.
Lower Coal field	...	2,130 feet.
Workable seams of Coal	6	
Middle Coal field......................	...	2,910 ,,
Workable seams of Coal	20	
Upper Coal field	...	1,560 ,,
Workable seams of Coal	5	
	31	6,600

Now all these seams, whether workable or not, have floors, as beds on which the Coals rest are termed. These consist of fine silt, called by the miners warrant (sometimes warren) earth, fire

* Transactions of British Association, Vol. xii. p. 46; and Sturgeon's Annals of Philosophical Discovery and Monthly Reporter of the Progress of Practical Science, Vol. i.

clay, and rock. In all the floors that I have examined, which are eighty-four in number, remains of Stigmaria *ficoides* have been met with. The floor of the feather edge coal, consisting of a few inches of brown coloured clay resting on rough sandstone, in a former paper read before the British Association in Manchester, was supposed to be the only exception, but latterly numerous instances of the occurrence of the Stigmaria have been found in the floor of that Coal. It is the only Coal in the whole of the Lancashire and Cheshire Coal-field which exhibits evidence of a strong current of water in its roof and floor, and it is a very irregular seam, often found wanting altogether. It presents the only example in Lancashire of the "*Simon*" fault of the Forest of Dean Coal-field. The rest of the floors all indicate great quietude of deposition, indeed, the greatest of any of the beds, and where they are thick and full of Stigmaria, the seams of Coal above them are generally valuable, shewing an intimate relation between the soil and its produce, if the theory of the vegetable matter now forming Coal, having grown where it is found, be true.

Coal floors shew no evidence of strong currents

of water necessary to drift forests of timber from neighbouring lands, but have every appearance of a hardened mud brought by sluggish water, with scarcely any current.

The presence of the remains of bivalve shells, and fishes, in cannel, clearly prove that it was formed under water; but in the Lancashire coal seams we have, as yet, found no remains either of fishes or shells, although there are frequently found in them regular partings of fine silt and fire clay, evidently deposited from water, full of Stigmaria rootlets, and, like the true floors. A thin layer of an inch of unctuous clay generally intervenes between the bed of Coal and its floor. But there is not any admixture of sand or clay in the Coal itself, to shew that it was drifted, into the places where it is now found, by currents of water. Nearly all the Coal seams, more or less, display evidence of common Coal plants, especially Stigmaria, Sigillaria, and Lepidodendra, pulverulent carbonaceous matter, like charcoal, or shew woody structure under the microscope.

On the other hand, the roofs or strata immediately above the seams of Coal nearly always present some evidence of currents of water.

They are of four kinds, namely, Sandstone, Bind (hardened silty clay), Black Shales (fine clay coloured with bitumen), and Black Bass (bituminous clay approaching to cannel).

Sandstone roofs present exactly such an appearance as a strong current of water flowing over a tract of luxuriant vegetation would now produce, namely, prostrate trees lying in all directions, mingled with sand. The tender and fragile parts of plants are broken and dispersed by the currents that prostrated them, or have since disappeared on the subsequent percolation of water, which first decomposed, and then removed them.

Blue bind roofs exhibit every appearance of a moderate current of water, sufficient to bring the clay, which on ceasing to be suspended in water, although sufficient to weigh down, and bury in fine grained mud, the delicate and small plants found in them, was not able to overthrow the Sigillaria, Ulodendra, Lepidodendra, and other large trees. For it must be remembered, that nearly all the upright specimens of the stems of fossil trees, found in our Coal measures, are large ones.

The black shale roofs indicate even a more

quiet and gentle flow of water, than those composed of bind, and show every appearance of having been a long time in formation, as the nearly total disappearance of plants by decomposition, and the dispersion of their carbon throughout the strata, as well as the abundance of shells of the genus Unio in the middle, and of the Pecten, Goniatites, &c. in the lower parts of the Coal-field prove.

The black bass roofs, in the upper Coal-field, afford an evidence of the very long periods of time which must have elapsed during their formation, as many of them are entire masses of bituminous casts of Cyprides, Microconchi, shells and fish bones, and teeth, mingled with decomposed vegetable and animal matter.

In the lower Coal-field, coarse gritstones and black shales abound, but the seams of Coal are few and thin.

In the middle Coal-field, fine grained white sandstones, and light coloured argillaceous deposits are plentiful, and the most numerous and valuable seams are there met with. In the upper field, so long as the rock deposits resemble those of the middle one, the seams are pretty

much the same, but as soon as they become red, and are mixed with beds of limestone, the seams become of little value, thus showing that the condition of the waters had some connexion with the production of the seams of Coal; for we find, that the strong currents of the lower Coal field were not favourable to the formation of thick and numerous seams of Coal, but that the tranquil and quiet waters of the middle one were; while the waters of the upper field, although equally quiet and tranquil, having been charged with peroxide of iron, and carbonate of lime, were not favourable to the formation of thick and valuable seams. Rocks highly charged with peroxide of iron, are generally sparingly stored with animal remains, whilst those containing carbonate of lime, are, for the most part, full of them. We thus see, that the distribution of plants and animals varied, according to the state of the waters they lived in. The general absence of fossil plants in limestones of all ages, has never yet, to my mind, been satisfactorily accounted for.

The occurrence of thick seams of Coal lying amidst the most tranquil of aqueous deposits, and the rareness of such seams in the coarse gritstones of the lower field, seem to prove anything but

that the vegetable matter now forming Coal was drifted into the places where it is found; else we should expect fully as great, if not a greater, amount of vegetable matter, where we find evidence of a strong current.

As before stated, rough gritstones, containing rounded pebbles of quartz, abound in the lower Coal-field; whilst the middle and upper measures, reaching to a thickness of four thousand four hundred and seventy feet, as far as I know, have never yet afforded a piece of mineral matter in their sedimentary deposits, of the size of a small pea. In two *seams* of Coal, namely, the four feet mine at Patricroft, and a small seam under it, the same mine at Pendleton, I have obtained rounded stones of several pounds in weight, but as both these specimens came from the neighbourhood of great faults, probably they may have been brought to the places where they were found, by other causes than currents of running water. They, however, are interesting, and very difficult to account for, being well rounded. Their composition is the same, though found in different seams and distant places, being of hard crystalline quartz, more resembling Gannister than any other stone in the carboniferous series.

The outsides of both stones are well coated with a covering of Coal, showing that they must have lain long in the places where they were found.

As previously remarked, dry land has been inferred to exist, during the formation of the carboniferous series, from the characters of the fossil plants discovered embedded in it. The true nature of these plants, however, is at present but little understood, and calculated to puzzle the most eminent recent botanists, rather than throw much light upon the soil upon which they grew. Wherever the plants grew, the strata, in which they are found, were no doubt deposited from water, and show no evidence of having been dry land. Had dry land existed during that period, some evidence of it would, in all probability, have been left during the deposition of the flags of the lower Coal-field, as we there find thin beds of fine sandstone, alternating with thin deposits of silty clay. The latter of which, —if exposed to the action of the sun or air for a few hours, even so short a time as the reflux of the tidal wave of our present seas—would have left some evidence of desiccation, and consequent contraction.

In the upper new red sandstone of Weston Bank, near Runcorn, in Cheshire, we have the first positive evidence hitherto discovered of dry land in England.

At Weston, in the rock above named, about thirty-two feet from the surface, and in the higher part of the deposit, there is a thin bed of red clay, from about half to three-quarters of an inch in thickness. This clay affords impressions of the feet marks of the Cheirotherium, Rhynchosaurus, several other reptiles, numerous worm marks, and beautiful lines of desiccation, similar to what a bed of moist clay would undergo, under a hot sun at the present day. The red clay was evidently deposited by water, which afterwards receded from it and left it uncovered. When this deposit was in a plastic state, the animals walked across it and left their tracks, subsequently the sun or air by desiccating the clay, produced wide cracks, and the water, at length returning, again filled both the feet marks and cracks, and made a beautiful cast of them in sand. Thus do these most interesting specimens, not only show us the tracks, left countles ages ago, of some of the most extraordinary animals that ever existed on our globe, but they afford us

proofs of a very quiet flow of water that deposited the red clay—the recession of such water—the drying and cracking of the clay by a hot sun or air, and the return of a sharp current of water, bearing along with it the sand that formed the casts of the moulds,—circumstances of great interest, to those who speculate on the physical condition of the globe at that remote period.

Numerous such thin beds of clay are to be met with in the Coal measures, alternating with beds of sandstone, formed of grains of different sizes, still no trace of desiccation is to be found like those in the new red sandstone last described. Such may have existed, yet all evidence of them in England has been lost; but Mr. Lyell, in vol. II., No. 4, p. 25, of the second series of the American Journal of Science, states, that he has discovered footmarks of an animal, resembling the Cheirotherium, in the middle of the Coal-field in Unity township, five miles from Greensburg, in Westmoreland county, Pennsylvania. The markings occur on slabs of stone, a few inches thick, between which are thin partings of fine unctuous clay, where casts of the animals' feet in sand are

left. Thin cracks filled with sand, also appear in the clay. These seem as if made after the animal had walked. Thus, these American flags present very similar appearances to Weston ones, before described.

Many of the fine beds of flag show very regular depositions of sand, alternating with clays, such as might, on first view, lead us to suppose them the effects of tidal action; but they are of small extent, and the direction of the currents which brought the materials of which they are composed, is often very variable, and much more difficult to ascertain than littoral deposits, by the present ocean, appear to be. Many of these beds of flag exhibit impressions of some body having acted upon them, when in a soft state, as a slab of the upper flag rock from Kerridge shows. (See plate I.) All these marks can be traced downwards, through several successive deposits of one-eighth to one-fourth of an inch each in thickness. In some instances a bed of flagstone, eight inches in thickness, will show impressions of the same size as those in the lithographic plate on its upper surface, and corresponding marks, in relief, on its lower surface; thus showing that

PLATE I.

Portion of Upper Flag containing impressions

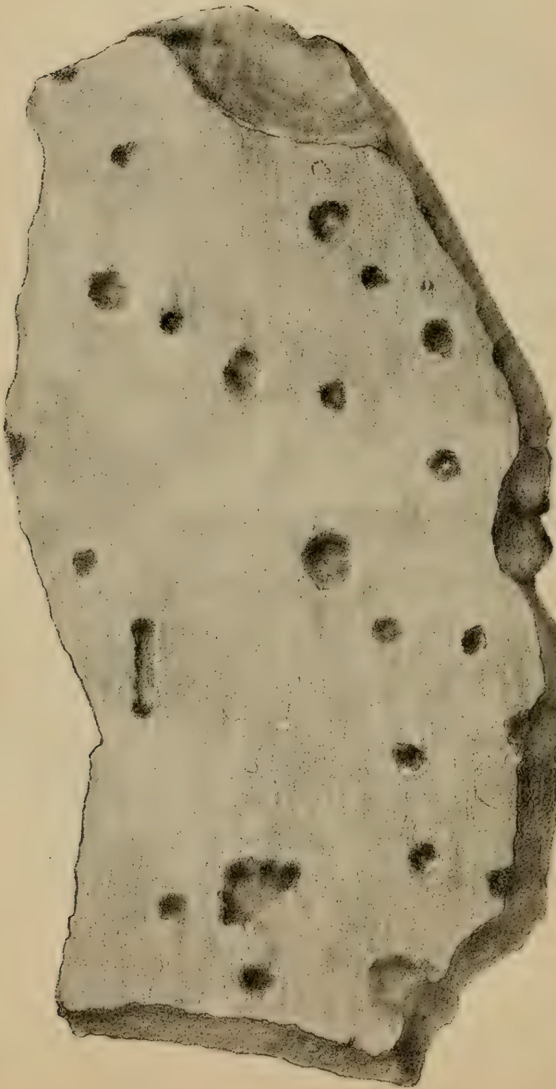


PLATE II.

Portion of Lower Flag from Todmorden shewing Casts of Annelide

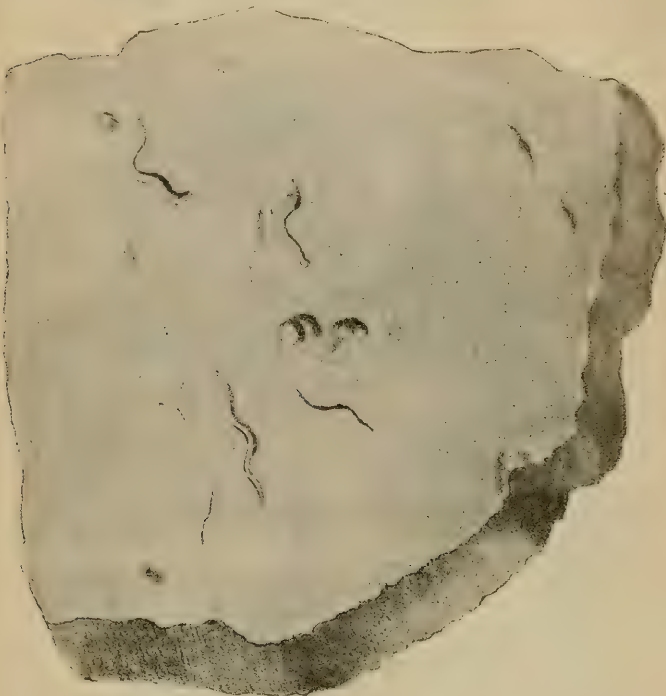
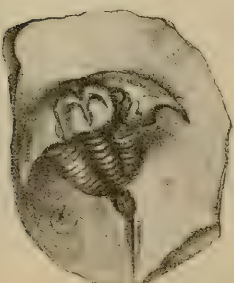


fig 2.



the force had acted throughout several laminæ of the stone.

In the lower bed of flags near Todmorden, I I have met with a specimen of fine grained sandstone, shewing several distinct casts of a small Annelide, described in plate II. fig. 1. And in a nodule of ironstone, presented to me by Mr. Francis Looney, F.G.S., found in one of the Bent mines, at Oldham, there is a beautiful impression of a long-tailed crustacean, resembling the Limulus *trilobitoides.* (See plate II. figure 2.)

The remains of fishes and shells give further evidence of the presence of water.

As before stated, it is from the remains of plants that dry land has been supposed to have existed during the carboniferous epoch. Such large trees as Sigillariæ, Ulodendra, Lepidedendra, and many other fossil remains, were considered to have grown on an insular spot; and it has been plausibly argued that hard wooded trees, like the genera Pinites and Pitus of Witham, were located on higher and drier grounds, while the numerous remains of

ferns, and other small plants, were attributed to low marshy land.

No reason was assigned for the rarity of specimens of ferns, showing remains of fructification,—although it is well known that, in the oolitic Coal-field, such plants are frequently met with in that state,—except that the floods swept down the plants at a period of the year when their fructifications were absent. The long processes radiating in quincuncial order from the Stigmaria, to a considerable distance, did not allow of its being so easily drifted, therefore it was allowed to have grown in the position where it is found, and called an aquatic plant. As it was always met with in the Coal floors, it was supposed to have been a kind of harbinger of dry land, filling up, by its rapid growth, the swamps, until a bed of soil was formed for the growth of the larger trees, like the Sigillaria, &c. This view was taken by many authors, who represented the vegetable matter, now forming coal, to have grown on the spots where it is now found on dry land. The parties who advocated the drift hypothesis, carried by currents of water the Stigmaria with all the rest of the plants into their *Mare Carboniferum*, where they formed

all the Coal seams. The various arenaceous and argillaceous deposits of the Coal measures were thus accounted for, but no sufficient reason was assigned for the Coal seams themselves containing so little of transported matter.

As before stated, the seams of Coal are generally found lying upon a fine deposit of hardened clay or silt, indicating great quietude in its formation, and scarcely any trace of a current. In fact, we have in the floor a fine rich soil, well calculated to have produced a luxuriant crop of vegetation, full of immense numbers of Stigmaria *ficoides*, now proved by the trees of St. Helens and Dukinfield, to be nothing more than the roots of Sigillaria.* So their presence under the seams of Coal, is now fully accounted for, being merely the roots *in situ* of the forests of Sigillaria, that have chiefly formed the beds of Coal found lying above them. These fossils are of great value in accounting for the true formation of Coal seams, and must for ever do away with the drift hypothesis, so far as concerns those seams in which they are found in the floors,

* Phil. Mag. for March, 1844, and October, 1845 ; also, Quarterly Journal of the Geological Society, for Nov. 1846.

and establish the rival theory, which attributes the formation of Coal seams to vegetable matter, grown upon the identical places where it is now found.

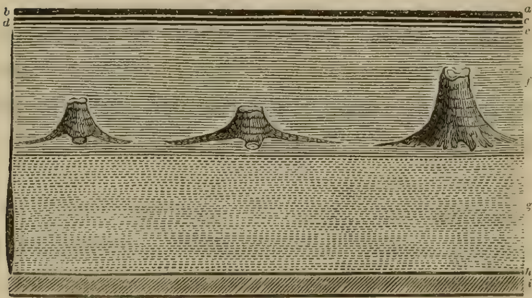
In most of the Coal seams of Lancashire, some evidence is found of upright stems of trees, for the most part Sigillariæ, standing upon the roof of the Coal. Professor Ansted, in Vol. I. p. 262, of his Treatise on Geology, in speaking of Sigillaria, says, "The great abundance of the large stems, referred to this genus, is a fact which seems to show that it was one of those to whose presence much of the solid matter of the Coal is due. Many instances are known, in which trunks or stumps of large trees of this kind are found close together, in an erect or highly inclined position; and this, not only in England, but also in the continental Coal-fields, and more particularly in that of St. Etienne, where a remarkable group has been described by M. Brongniart. It must not be supposed, however, that the trees grew upon the spot where they are thus singularly arranged; it is more probable that they may have been caught, and stopped in their passage down a rapid stream, and, like the *snags* on some of the great American rivers, have been detained till the

lower portion was firmly embedded in the rapidly forming sandstone." Whatever evidence of *snags* the fossil trees examined by the above learned author may have presented, most of the specimens found standing erect in Lancashire, show every appearance of having grown where they are now found. Remains of Sigillaria can also be generally found in the coal itself.

Although the stems of Sigillaria have been generally noticed in the roofs of Coal seams, it is by no means to be inferred that they are not to be found in other portions of the carboniferous strata. They no doubt have been found more frequently in the roof than other places; but that part can be better examined than other strata in a mine. The fossil trees at St. Helens, all Sigillaria, were four in number, and occurred in a deposit of gray indurated silty clay, lying about eighteen yards two feet above a foot coal, and fourteen yards one foot under a yard seam. The bases of the stems lying about eight feet above a white gritstone rock, and the stems proceeding upwards in the warren, which was completely traversed, as far as it could be traced, by Stigmaria *ficoides*; so if the whole of the rock had been on in the quarry, the stems would

probably have reached up to the Roger seam of Coal.

Fig. 1.*



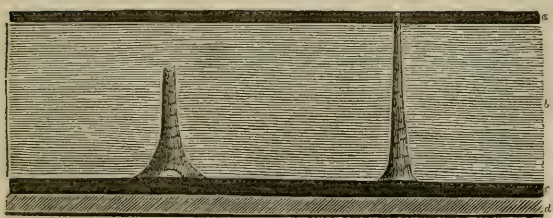
		yds.	ft.	in.
ROGER MINE.	*a* Coal	0	2	0
	b Dirt	0	1	0
	c Coal	0	0	9
	d Dirt	0	0	6
	e Coal	0	1	0
	f Warren containing the fossil trees	17	0	0
	g White gritstone	16	0	0
	h Coal and dirt	0	1	0
	i Floor full of Stigmaria *ficoides*.			

In the Duchess of Lancaster mine at Pendleton, near Manchester, have been observed a great number of fossil trees, most of which exhibited undoubted characters of Sigillaria. They stood

* The seams of Coal and fossil trees in all the three wood-cuts, are drawn upon a scale of double the size of the other strata, and are merely for the purpose of showing the *position*, and not the *characters* of the fossils.

erect on the seam of Coal there, seven feet in thickness, some of them showing small portions of their roots, whilst others rested with their stems upon the Coal. These trees I measured twenty-five feet upwards in the Blue bind, but Mr. Ray, the intelligent engineer of colliery, had traced one which went through the floor and into the seam of the Albert Coal. A portion of this stem, converted into Coal, is now in the museum of the Manchester Geological Society. In the strata near the bases of the stems occur plenty of Pecopteris *nervosa.*

Fig. 2.



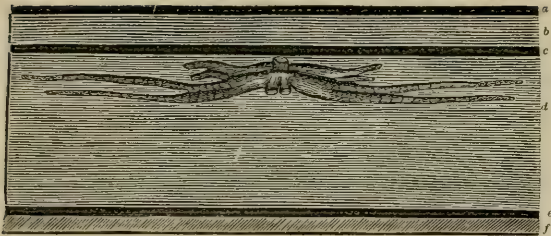
	yds.	ft.
a Coal Albert Mine	1	0
b Blue Bind and Shale (fossil trees)	19	0
c Coal, Duchess of Lancaster	2	1
d Floor, full of Stigmaria *ficoides.*		

Lately has been discovered in the floor of the Victoria mine, Dukinfield, near Manchester, at the

depth of eleven hundred feet from the surface, a magnificent specimen of Sigillaria, which exhibits in the stem the respective characters of the species *pachyderma*, *reneformis*, and *organum*, and true Stigmariæ traced eighteen or twenty feet as its roots. The stem was about two feet high, and could not be traced into the Coal and Cannel seam above. Four main roots appeared to have proceeded from the base, but only one has been preserved entire and lodged in the museum of the Manchester Geological Society. This, after proceeding some distance, divides into two roots, and each of these latter into two more, which run in a horizontal direction as Stigmaria, at a depth of two feet under the Coal. Their extremities have not been reached, although they were traced upwards of twenty feet.

The matrix in which they occurred was a dark coloured fire clay, which contained so much carbonaceous matter as to prevent the rootlets of Stigmaria or any other fossil remains from being easily traced in it; but it was very evident that the destruction of an immense number of these bodies had caused the dark colour of the clay, as they could be distinctly seen on dividing the moistened clay with a penknife.

FIG. 3.



		yds.	ft.	in.
a	Coal, Stone Mine	0	2	6
b	Black Shale, &c	4	0	0
c	Canal or Two Feet Mine	0	2	2
d	Tender Metals, containing the fossil tree, Black Bands and Rock	22	0	0
e	Coal, Peacock Mine	0	2	4
f	Floor full of Stigmaria *ficoides*.			

The above trees have been alluded to for the purpose of showing the different positions which they are met with, and not as the only instances of upright specimens which have been found in the Lancashire Coal-field. For after eight years' observation, I am led to believe that most mines of any considerable thickness, if carefully examined, will give some evidence of upright trees.

The resemblance of seams of Coal to beds of peat, has long been advanced as a proof that Coal was formed from vegetable matter, grown upon the places where it is now found. All the early

advocates of this theory, comprising Jamieson, De Luc, Brongniart, and others, gave strong evidence in support of their views; but their supposition, of raising and depressing the surface of the earth so as to have it alternately land and water for every seam of Coal, was not borne out by any such similar changes of position now observed on the crust of the globe. Mr. Bowman's paper on the origin of Coal, published in the 1st volume of the transactions of the Manchester Geological Society, is unquestionably the most valuable treatise on forming Coal by subsidence; and satisfactorily accounts for the dividing, thickening, and thinning of seams of Coal, and was the most useful memoir on the origin of Coal which had then appeared.

It was owing to the observations of Mr. Charles Darwin, on the coast of Patagonia, that geologists were first presented with a series of phenomena of the gradual rising of land, it then being in a state of repose, for a considerable period, and again rising. This alternation of elevation and repose being repeated many times. Upon first reading his work, I immediately saw a series of phenomena, the reverse of which, I had long been convinced, had taken place during the formation of our beds

of Coal, and that, in all probability, they were the opposite of what was taking place on other parts of the earth's crust at that time.

Direct evidence of the subsidence of land is difficult to obtain, but Mr. Darwin, at p. 475, of the second edition of his Journal, states, "Nevertheless, at Keeling Atoll, I observed on all sides of the lagoon of cocoa-nut trees, undermined and falling, and in one place the foundation posts of a shed, which the inhabitants asserted had stood, seven years before, just above high water mark, but was now daily washed by every tide. On enquiry, I found that three earthquakes, one of them very severe, had been felt here during the last ten years." In addition to the mass of evidence previously known, as to the subsidence of land, Mr. Darwin, at page 171, observes, "Every thing in this southern continent has been effected on a grand scale; the land from the Rio Plata to Tierra del Fuego, a distance of twelve hundred miles, has been raised in a mass, (and in Patagonia, to a height of between three hundred and four hundred feet,) within the period of the now existing sea shells. The old and weathered shells, left on the surface of the upraised plain, still partially retain their colours. The

upraising period has been interrupted by at least eight long periods of rest, during which, the sea ate deeply back into the land, forming, at successive levels, the long line of cliffs or escarpments, which separate the different plains as they rise like steps one behind the other. The elevatory movement and the eating back power of the sea, during the periods of rest, have been equable over long lines of coast; for I was astonished to find that the step-like plains stand at nearly corresponding heights, at far distant points. The lowest plain is ninety feet high, and the highest which I ascended, near the coast, is nine hundred and fifty feet, and of this, only relics are left in the form of flat gravel capped hills. The upper plain of Santa Cruz slopes up to a height of three thousand feet, at the foot of the Cordillera. I have said, that within the period of existing sea shells, Patagonia has been upraised three hundred to four hundred feet. I may add, that within the period when icebergs transported boulders over the upper plain of Santa Cruz, the elevation has been at least fifteen hundred feet. Nor has Patagonia been affected only by upward movements; the extinct tertiary shells from Port St. Julian and Santa Cruz, cannot have lived, according to Professor E. Forbes, in a greater depth of water,

than from forty to two hundred and fifty feet; but they are now covered with sea-deposited strata, from eight hundred to a thousand feet in thickness; hence, the bed of the sea, on which these shells once lived, must have sunk downwards several hundred feet, to allow of the accumulation of the superincumbent strata. What a history of geological changes does the simply constructed coast of Patagonia reveal!"

In the early part of this paper, the evidences of periodical subsidences, and periodical rests in those subsidences, as exhibited by the beds of fossil shells, were brought before your notice; they showed great regularity of motion in the earth's crust, extending during vast periods of time. Is it likely that such a series of phenomena should at once change? No.—It is much more philosophical to suppose that it continued on during the whole period of the formation of the carboniferous strata, and the successive forests of fossil trees entombed in them, standing on the exact spots where they grew and flourished, to most minds must satisfactorily prove it. The evidences of the periodical states of elevation and repose of the Patagonian coast, are but the reversed action of what has taken place during

the deposition of our Coal seams. Every seam of Coal indicating a period of rest of the earth's crust, which allowed the growth of a forest of trees; whilst the sandstones, shales and binds, give us a correct measure of the rate of subsidence, and the force of the currents caused by such changes of the surface of the globe. As before stated, there are, in the Lancashire Coal-field, one hundred and twenty beds of Coal, which would require as many epochs of rest, and the same number of subsidences, to account for their origin, a period of time, vast to our ideas, but small in the history of the earth.

In a former paper (p. 178, Vol. i. of the Transactions of the Manchester Geological Society) I have stated, that the Coal measures presented some appearance of having been deposited in an estuary; but further observations, and the great superficial extent of the formation, now lead me to believe that they must be considered more of a *marine* character, and that the currents which brought the *debris*, did not altogether proceed from rivers running into the sea, or by tidal action, but were chiefly produced by the subsidence of the bottom of the ocean itself. The occurrence of the Cypris and the Unio, in

the upper Coal measures, has been considered indicative of the fresh water origin of those strata; but when these fossils are found in company with remains of the Megalichthys, Holoptychius, Cælacanthus, Platysomus, Palæoniscus, and other genera, heretofore considered as of decidedly marine origin, their diagnostic value ceases, even if all these genera were confined to fresh water; but it is well known that such is not the case, but that many are found in salt water.

Independently of this, we must take into consideration the vast extent of the true Coal-fields of Europe, all of which have, most probably, been once united and formed under similar conditions; and the evidence they present of the action of currents of water, is very different from what we now witness at the mouths of estuaries or on beaches, for we find no deposits in them resembling those of the latter. Professor H. D. Rogers, in his admirable paper on the origin of the Appalachian Coal strata, at p. 469, states "that it may fairly be questioned whether any sensible proportion of river silt could spread itself to the distance of one hundred and fifty or two hundred miles seawards." The extent of this immense Coal deposit, as well as its accompanying strata and organic remains,

like our European field, seems to require an ocean for its formation. This ocean would be of a very different character to any now known to cover the surface of the globe, exhibiting an uniformity and shallowness unknown at the present time ; and such circumstances would doubtless influence the tidal wave and produce phenomena unlike those observed at this day.

As the present ocean and its tides will not, therefore, account sufficiently for the different deposits of the Coal measures, allow me to direct your attention to vertical sections of those strata, and show the materials of which they are composed, and how they change and graduate into one another.

The size and nature of the particles composing the different beds give us some idea of the currents of water that brought them. I propose to ascertain the rate of subsidence from the same source, and to attempt to show that the currents are but the effects of such subsidences.

The diagram, plate III, figure 1, represents a section of part, and the richest portion, of the lower Coal-field at Staly-bridge, near Man-

chester, proved in sinking Mr. Woolley's shaft. It commences a little under the Gannister Coal, and terminates with a portion of the upper Flag Rock, and is interesting from the circumstance of the roof of the upper seam of Coal containing an abundance of Goniatites, Pecten, Posidonia, and other marine shells. The vertical black line indicates by its varying thickness the degree of rapidity of the subsidence of the bottom of the sea, at the particular period when the part of the deposit at which it is opposite was forming, as well as the strength of the current produced by such alteration in level.

The Sandstones, Rock Binds, Shales, Metals and Binds, and Floors, indicate diminishing rates of subsidence, and the breaks in the line are periods of absolute rest, during which the vegetable matter, now forming Coal, grew.

The diagram, plate III, fig. 2, shows a section of the St. George's Colliery, near Manchester, the property of Edmund Buckley, Esq., M.P. It commences with the upper portion of the middle Coal-field, and terminates upwards with the lower and richest part of the upper division. This section is remarkable for the number of

Coal seams occurring in a short distance, from the compound nature of some of the seams, and from the abundance of casts of a Cypris, mingled with the remains of large fish. The black line here also marks the rate of subsidence of the crust of the earth, and the velocity of the water, as in the other section.

Both sections are taken for the purpose of proving the hypothesis, that the currents of water which carried the arenaceous, argillaceous, and calcareous deposits of the coal measures, were caused chiefly by subsidence of the bottom of the sea, and that seams of Coal indicate periods of rest, during which such currents ceased to flow, and thus allowed of the growth of vegetable matter, sufficient for their formation.

The first section (see plate III, fig. 1,) commences with the floor of the "Parson's Mine," which is composed of a crystalline stone, known by the name of Gannister. It is formed of a fine grained silt, cemented together by a silicate of lime or alumina, and contains an abundance of tree roots, (Stigmaria *ficoides*) evidently *in situ*. When these trees grew, the soil which supported them could not have been deeply covered with

SECTIONS SHEWING THE INTENSITIES OF SUBSIDENCE AND CURRENT

and the periods of rest during the formation of the COAL MEASURES

FIG. 1.
Section of part of Mr. Woolley's Colliery STALYBRIDGE

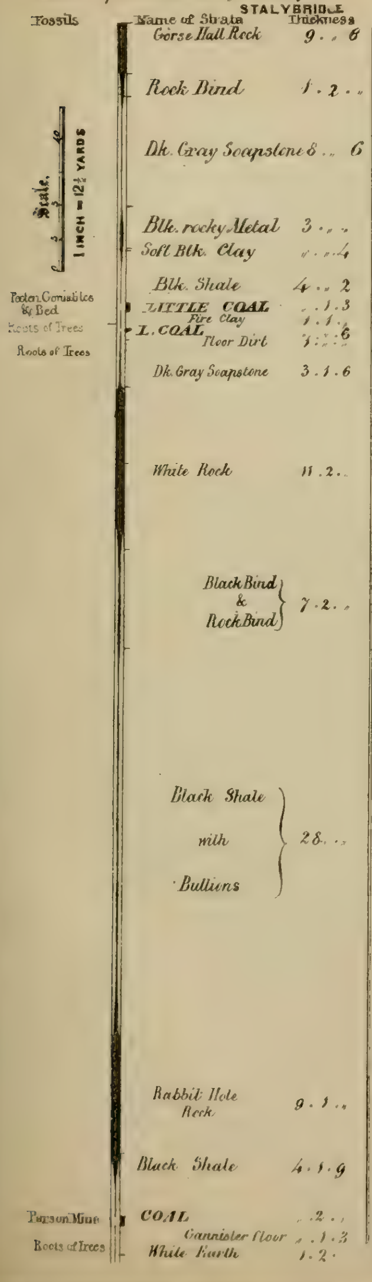
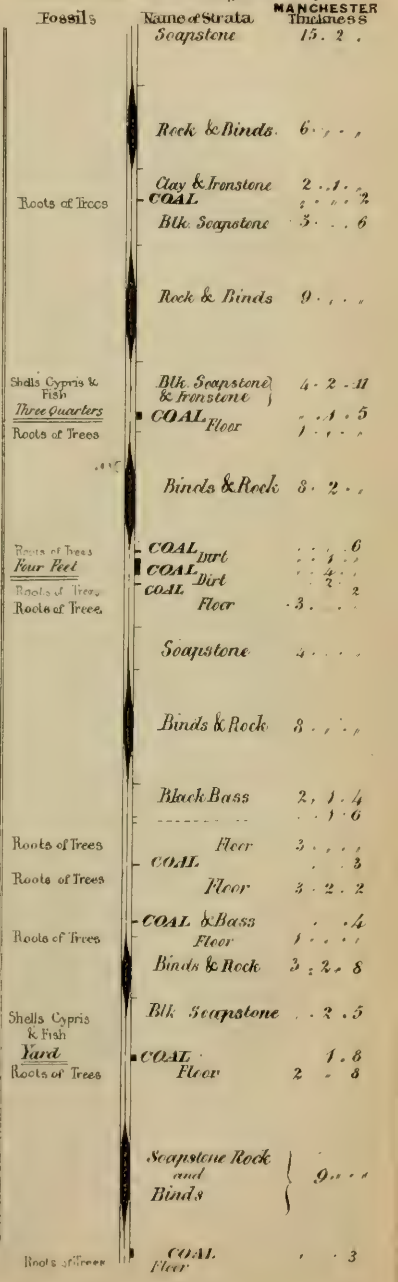


FIG. 2.
Section of part of St. George's Colliery MANCHESTER



water, and it must have remained in a state of repose for a long period, so as to allow of the growth of sufficient vegetable matter to form the two feet of Coal. After the production of this Coal seam, the surface slowly and gradually subsided, and the vegetable matter being partially decomposed, a portion of its carbon mingled with the fine clay composing the Black Shale, brought by a current caused by such slow and gradual subsidence.

The subsidence then increased, and caused a quick current, which brought the sand now constituting the "Rabbit-hole Rock." Again the subsidence diminished during the formation of the Black Shale with ironstone nodules, and then gradually increased during the formation of the Black Bind, Rock Binds, and White Rock. The dark gray Soapstone indicates a period of approaching rest. The Floor-Dirt was then formed, on which grew the vegetable matter composing the six-inch seam of Coal. A slight and partial subsidence then appears to have taken place, and formed the four feet of Fire clay whereon grew a fresh crop of Sigillariæ that formed the one foot three inches of Coal. The subsidence then appears to have been very gradual, so as to allow of the decomposition of vegetable and

animal substances, and thus colour with their carbon the Black Shales, and the existence of a bed of Pecten, Posidonia, and Goniatites, now found lying in them. According to Sir H. De La Beche's table, p. 403, in the appendix to his Geological Researches, the Pecten is now found in sands, sandy mud, and mud at depths from 0 to 20 fathoms; so it is fair to assume that these creatures lived in about 10 fathoms of water. A gradually increasing rate of subsidence then appears to have been in action during the formation of the dark gray Soapstones, Rock Bind, and Gorse-Hall Sandstone Rock.

The section of St. George's colliery, plate III, fig. 2, presents nearly similar dynamical and statical conditions of the earth's surface to that last described; but the periods of repose appear to have been more frequent, and the subsidences more gradual, than in the former instance. The phenomena, however, are, on the whole, so similar that it will be unnecessary to go through all the changes of the earth's surface, at the period they were made, a second time, except by noticing the Black Basses over the yard and three quarters mines. These strata, by the immense mass of casts, Cyprides, and disjointed teeth, scales, and bones

of sauroid and other fishes, scattered throughout them, as well as by the occurrence of the Unio—a shell resembling the Modiola—and the Microconchus, prove that a considerable period of time was requisite for their formation.

The fossils, in the first case, occur over a space of about two feet, in a bass, which is composed of fine clay, mixed with bituminous matter, resembling the indurated black mud which we now find at the bottom of stagnant pools, in which there is much decomposing vegetable matter. After the growth of the vegetables constituting the yard Coal, the subsidence must have been very slow and gradual, so as to allow time for the complete decomposition of all the vegetable matter, and the existence of the animals whose remains are now found there. From the fragmentary state of the portions of fish, mixed with the casts of Cyprides, there is every reason to believe that their edible parts were consumed by the Cyprides, in a similar manner to the removal of decomposing animal matter by the small crustaceæ of our modern waters.

The Bass, over the three quarters seam of Coal, resembles that over the yard mine, in the nature and condition of the organic remains found em-

bedded in it; but the under portion of it, nine inches in thickness, is a rich iron ore. The whole mass of the Bass and ironstone, like the Bass above the yard Coal, teems with remains of Cypris and Microconchus, detached bones, scales, and teeth of fishes of the genera Megalichthys, Holoptychius, Cælacanthus, Platysomus, Palæoniscus, Diplopterus, Ctenoptychius, and shells of the genera Unio and Modiola, all mingled together.

The three sections of strata containing fossil trees, heretofore referred to, may also be brought as proofs to show the change of level and condition of the earth's surface, at the period of their formation; but their changes in structure, especially those of the two last, are so regular and slow, as to show but little variation in the rate of subsidence. The St. Helen's section commences with a mass of vegetation now forming the foot coal, grown during a period of repose of the area on which it is found. It then subsided, at first slowly, but gradually increasing. The subsidence was at length rapid enough to prevent the growth of plants, so long as the White Sandstone Rock was in the process of formation. When this was done, however, it became gradually slower, so as to allow of the formation of the Warren, and the growth of the Sigillariæ found in it.

All these instances prove the existence of *land covered by water*, but no *dry land*, and confirm Brongniart's opinion, formed from the examination of Stigmaria, that the Sigillaria was an *aquatic* plant.

Sufficient evidence has not been adduced to prove that the various other plants found in the coal measures were grown on the places where they are now found, for we have not been able to detect their roots *in situ*. This remains to be done.

With respect to the Sigillaria, there can scarcely be a doubt but that it grew in water, on the deposits where it is now discovered, and that it is the plant which in a great measure contributed to the formation of our valuable beds of Coal.

In this, my first attempt to connect the currents which existed during the deposition of the Coal measures, with the rate of subsidence of a portion of the earth's crust, I have adduced evidence to prove that the subsidences during the period under review were of such a character, in general, as to cause slow and gradual movements, similar to what Mr. Babbage avers would arise from the contraction of the earth's crust by the radiation of heat,

rather than paroxysmal disturbances, similar to those which dislocated the carboniferous series, at intervals, long after its formation.

Whatever the cause of the numerous subsidences that have evidently taken place in the crust of the globe, it must certainly have been *deep seated*, and acted at intervals over vast periods of time, commencing long before the formation of the Protozoic rocks, extending over the whole of the Palæozoic rocks, and up to the latest Tertiary deposits.

We are at present in want of a correct vertical section of the earth's crust, showing the materials composing its various beds, and the nature of their organic remains. When this is supplied, we shall be enabled to trace back the physical history of our globe, and furnish the mathematician with data from which to calculate, with absolute certainty, the changes which have taken place in the solid particles of our planet, and to determine whether some of the most important of them have not been effected by the slow and silent process of the radiation of heat, rather than by more actively energetic causes.

IV.—*Sketch of the Drift Deposits of Manchester and its Neighbourhood.* By E. W. Binney, Esq.

(Read January 12, 1847.)

Introductory Remarks.

In other communications,* the author has endeavoured to give to the public what information he possessed relative to the older stratified rocks lying under the town of Manchester, as well as the superficial deposits which hide such rocks from our view. Both these papers were mere outlines, and were intended to be worked out in detail, when the completion of the Ordnance survey should furnish him with accurate maps and correct levels. Good maps are of the utmost importance to geologists, in all their investigations, but more especially in the examination of the Drift, as the superficial

* Vol. i. p. 35 of the Transactions of the Manchester Geological Society.

beds of clay, sand, and gravel, are now termed; and it is only by a series of correct levels that the phenomena of that deposit can be well studied, and their origin correctly ascertained. Although he has not yet been so fortunate as to obtain the assistance required, to enable him to give such an account of the Drift as he designs, yet he will give what particulars he has collected.

The examination of the older fossiliferous rocks, rich with the remains of organic life, has generally attracted the attention of geologists, to the exclusion of the Drift, which has been but too often considered as a dry and uninteresting study. My intention is to attempt to dispel this delusion. However delightful it may be to the human mind to examine the "medals of creation," as Cuvier aptly denominated fossil organic remains, and to trace back through countless ages the successive races of beings that have formerly peopled this globe—performed the parts for which they were designed, and then ceased to exist; to investigate the various forms of vegetable life that deprived the atmosphere of its surplus carbon, for the double purpose of forming our invaluable beds of coal, and at the same time fitting the air for the respiration of animals of a higher order;

and to examine the wonderful chemical agencies that have been in operation in the great laboratory of nature, in order to prepare our metallic and mineral treasures; still, the last great physical causes which have operated on the face of the globe, and adapted it for the habitation of man, deserve our attention in an equal, if not more pre-eminent degree.

It is to this last and finishing stroke of the Creator, that the earth chiefly owes its present arrangement of land and water, its beautiful variety of hill and dale, and its different kinds of soils for the support and nourishment of the vegetable kingdom—that wondrous agent for the conversion of brute into organic matter, which fits it for food for the use of the animal creation, and man himself.

At present, it is not intended to go into the numerous advantages to mankind which the various deposits of Drift afford in dry soils, beds of brick-clay, and surface springs of water; I shall confine myself to the consideration of the formation of soils for the support and nourishment of plants.

In the memoirs before alluded to, it was shown

that the chief part of the district around Manchester, before it was covered with Drift, consisted of upper new red sandstone rock, with slight portions of lower new red sandstone, magnesian marls, and upper red marls, and the hard sandstone and limestone rocks, and cold clays and shales of the coal-fields of Manchester and Pendleton—all deposits in their primeval state, capable of supplying little nourishment to vegetation.

It is to the period when the Drift was formed that the greatest part of the soils of this and other countries owe their formation, admixture, and arrangement. Then it was that the earth, to use an agricultural term, underwent the process of a long fallow. During Professor Agassiz's Glacial Epoch, intense frost and cold split and rent the hardest rocks asunder, immense glaciers ploughed up the sides of the mountains, huge icebergs, freighted with countless varieties of stones, floated on the waters, and torrents scattered and dispersed the *debris* over the plains. Rocks of all ages were thus brought together for the purpose of furnishing the various elements required by the vegetable world. A period of wintry desolation for a time existed, when this part of the earth's surface, from the evidences left, must have been

nearly destitute of living inhabitants, whether of animals or plants. Sterile it might be for a time, like the furrowed field exposed to the winter's frosts, but it was for the purpose of ultimately rendering it more fertile. For, most probably, the luxuriant vegetation at present existing on the globe, in a great measure owes its origin to the Drift epoch, in the same manner as the rich crop of wheat may be traced to the previous fallow.

In the Edinburgh New Philosophical Journal for January, 1847, Charles M'Laren, Esq. F.G.S. states the following as probable Causes of the Cold of the Glacial Epoch :—" Poisson, an eminent French mathematician, proposed an ingenious theory to account for the more intense cold which anciently prevailed in several parts of Europe, as evinced by the phenomena I have described, and many others. It has been deduced from observations made by the late eminent Prussian astronomer, Bessel; that our sun, with the planetary system attached to him, is moving through the celestial spaces, in a determinate direction, at the rate of three million eight hundred thousand miles per day. (Humboldt's Cosmos, p. 152, Eng. Ed.) Now, as the stars,

which are the sources of heat, are very unequally distributed in the heavens, Poisson thought that the solar system, in its journey towards the constellation Hercules, might pass through spaces of very different temperatures ; and that, at some ancient and remote period, it might have passed through a region of the heavens much colder than that in which it is now moving.

"A much simpler explanation of the change has been proposed by Mr. Lyell. Founding on principles developed by Humboldt, he observes that the climate of any part of the globe depends, in a great degree, on the distribution of sea and land. The east side of all extensive continents, in the extra tropical regions, has a warmer summer and a colder winter than the western. The extremes of heat and cold, for instance, are incomparably greater in Lower Canada than in the Oregon territory, though they are both in the same latitude. Now, if North America, at one time extended much farther eastward ; if, for instance, it occupied all the portion of the Atlantic between Newfoundland and Britain ; in that case it is certain that Britain would have had the inhospitable climate of Labrador, or even one still more severe, like that of Greenland. There are

various facts which point to the state of things here put hypothetically. Thus the fresh water strata of the Wealden group of rocks, from their extensive range and great thickness imply that a river, as large as the Mississippi, had its estuary in England; and such a river could not exist, unless a tract of land one thousand, or two thousand miles in breadth, in connection with the British isles, had occupied the eastern part of the Atlantic. (See Lyell's Elements, Vol. i. p. 431.) Again: the same able geologist found evidence in the carboniferous rocks of North America,—that the coarser materials composing them came from lands lying to the eastward, and now covered by the Atlantic. (Travels in North America, Vol. i. p. 86.) Finally, Professor Edward Forbes, in a most interesting memoir recently published, has shown, from the relationship between the Fauna and Flora of the British Isles and of North America, that either the one has derived a certain portion of its animals and plants from the other, or that both have derived them from land now sunk in the intervening ocean." (Memoirs of the Geological Survey of Great Britain, Vol. i. p. 336-402.)

In other publications my endeavours have been to show the great value, to all classes of society,

which the study of this deposit is calculated to yield; and, having now shown that it is equally full of proofs of the wisdom and goodness of our beneficent Creator, in preparing the world for its present inhabitants, let us investigate the appearances which this deposit presents in the neighbourhood of Manchester. It is only by carefully observing the phenomena, and comparing them with the effects now being produced, that we can arrive at the true causes which have been in operation.

Slight Description of the Drift of Manchester, and its Neighbourhood.

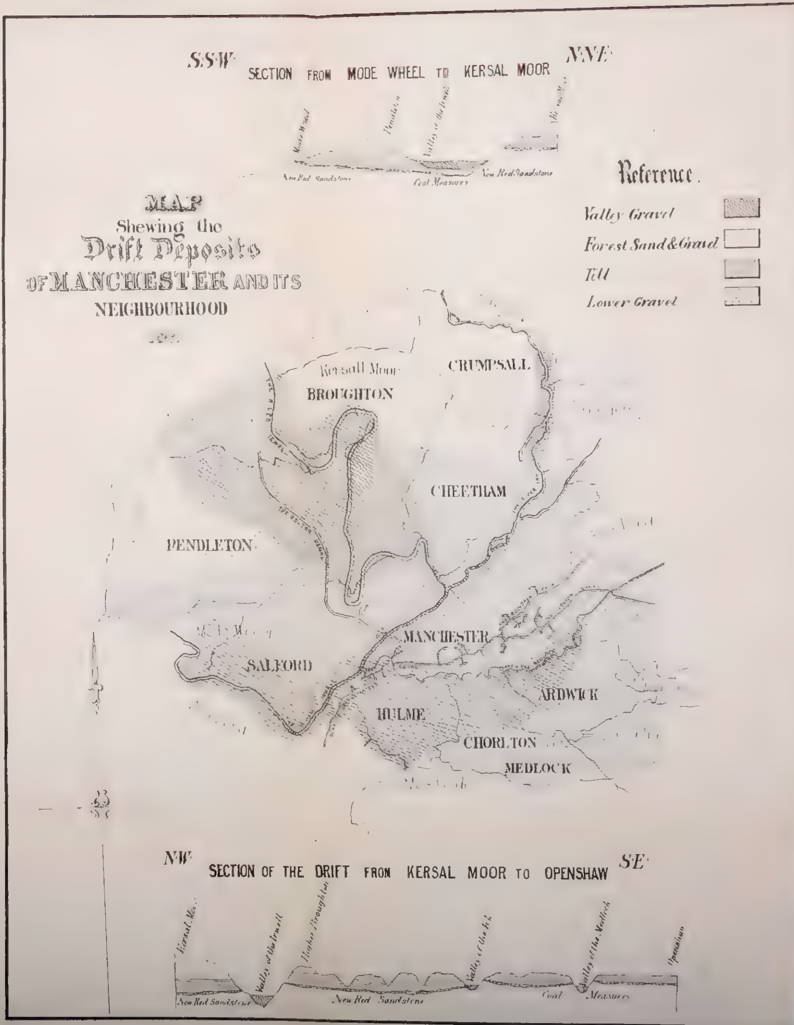
In the following remarks the *foreign* Drift, will alone engage our attention, without any mention being made of the *local* Drift; and it is intended, for the most part, to confine our observations to the townships of Manchester, Ardwick, Beswick, Bradford, Chorlton-on-Medlock, Hulme, Salford, Pendleton, Cheetham, Crumpsall, and Broughton. In describing the different deposits, we will con-

sider their permeability by water, a property which is generally noticed even by the most superficial observers, and of great importance to the health of a large town.

Generally speaking the older strata, in the vicinity of Manchester, both carboniferous and new red sandstone, are so thickly covered with Drift, as to affect, only in a small degree, the hydrometrical state of the subsoils on which the town and its suburbs are erected. The first named deposit has scarcely any houses erected immediately upon it; and although the latter, in the lower parts of the boroughs of Manchester and Salford, has a considerable number resting upon it, they are very few in comparison with those situated on the Drift. Both formations present irregular surfaces, much abraded, and rising up into the Drift, higher in some situations than in others, as shown in the section No. 2. It, no doubt, is owing to this irregularity of surface that the lowest bed of gravel and sand, hereafter described, is so uncertain in its occurrence, and so very variable in its thickness. The valley-gravel (No. 1) is never found beyond a certain height above the level of the Irwell; and its exact height being once determined, it is very easy to trace through the town.

THE DRIFT IN AND ABOUT MANCHESTER MAY BE CONVENIENTLY DIVIDED INTO THE FOLLOWING DEPOSITS, IN THE DESCENDING ORDER.

CHARACTERS OF DEPOSIT.	THICKNESS.	LOCALITIES.
No. 1.—A bed of coarse gravel, composed of various sized Azoic, Palæozoic, and Triassic rocks, well rounded, parted with layers of fine sand, and sometimes beds of sand, without pebbles; exhibiting every appearance of having been deposited by water; most frequently stratified, but sometimes unstratified. On the top of this is generally found about three or four feet of silty loam.	0 to 12 Yds.	In the valley of the Irwell, Lower Broughton, and, generally, more or less, in the beds, and on the sides of the three great valleys near Manchester.
No. 2.—A deposit of sharp forest sand, parted with layers of gravel of same rocks as No. 1, and having every appearance of a regular deposit by water, distinguishable only from No. 1 by its being found at greater elevations, containing more sand, and being, generally, more regularly stratified. It sometimes contains thin beds of Till lying in it.	0 to 25 Yds.	Irlams-o'th'-Height, Pendleton, Kersal-moor, Higher Broughton Prestwich, Cheetham-hill, Harpurhey, Crumpsall.
No. 3.—"Till:" a mass of strong brown clay, in which are mingled the same kinds of rocks as those in Nos. 1 and 2; of sizes from six tons in weight, to small pebbles; some rounded and partly rounded, and others quite angular—especially coal measure, and magnesian limestone rocks, without any order of deposition—great and small stones being mixed together indiscriminately;—quite impervious to water, and well known as valuable brick-clay, and from its being the deposit which yields *striated* or *scored* stones. Several beds of fine laminated silt and patches of sand are found in it.	0 to 30 Yds.	The brick-clay of Manchester, Salford, Strangeways, Cheetham, Beswick, Bradford, Ardwick, Openshaw, and Longsight.
No. 4.—A bed of sand, or coarse gravel, having the pebbles (consisting of the same kinds of rocks as Nos. 1, 2 and 3) well rounded, sometimes, but not always, occurring under the brick-clay, often stratified, and at other times unstratified. It affords good springs of bright water.	0 to 11 Yds. but seldom above 2 or 3 Yds.	In the valley of the Irwell at Pendleton Colliery, Cheetham-street, George's-Road, Beswick, Victoria Park, and under the Till in the higher part of King-street and Spring Gardens.



S.S.W.
SECTION FROM MODE WHEEL TO KERSAL MOOR
N.N.E.
Pendleton
New Red Sandstone
Coal Measures
New Red Sandstone
Reference.
Valley Gravel
Forest Sand & Gravel
Till
Lower Gravel
MAP
Shewing the
Drift Deposits
OF MANCHESTER AND ITS
NEIGHBOURHOOD
Kersall Moor
CRUMPSALL
BROUGHTON
CHEETHAM
PENDLETON
MANCHESTER
SALFORD
ARDWICK
HULME
CHORLTON
MEDLOCK
N.W.
SECTION OF THE DRIFT FROM KERSAL MOOR TO OPENSHAW
S.E.
Kersal Moor
Valley of the Irwell
Higher Broughton
Valley of the Medlock
Openshaw
New Red Sandstone
New Red Sandstone
Coal
Measures

Probably the deposits mentioned above will not always be found in the perfect order there laid down; no doubt some of them may be wanting, at places; especially Nos. 4 and 2, which have often been removed; but whatever objections are made to it, this must be taken as the first attempt to describe the Drift Deposits of the neighbourhood. It will afford facilities for describing the relative permeability by water of the upper deposits in the neighbourhood of Manchester. The different townships will now be described:—

MANCHESTER.

(SEE MAP.)

The site on which this township stands is nearly all strong brick-clay (No. 3,) quite impervious to water; varying, generally, in thickness, according to the height of the town above the level of the river Irwell. Along the banks of the Medlock, from near Mr. Barlow's dye-works, below Every-street, to near Ardwick Bridge, there is a small portion of upper new red sandstone and gravel (No. 1). From above Scotland Bridge, on the Irk, in a line running a little south of Long Millgate and Todd-street, above Corporation-street, and part of Cross-street, to below the town-hall in King-

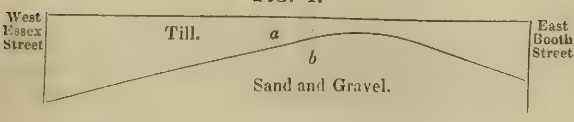
street; and then along the slightly-rising ground through part of Brazennose-street, across Deansgate, to the east end of St. John's church; and then through Camp-field, in a curve, to the bottom of Deansgate, and the tract of land lying between these parts and the Irk, Irwell, and Medlock, down to Castle-field, it is upper new red sandstone on the river banks, and a deposit of gravel (No. 1) in the higher portion; both forming good dry subsoils. With the above exceptions, the surface of the township of Manchester consists of Till, and must be considered as placed on a stiff clay, and its drainage effected entirely from the undulatory character of the ground, and not from the porous nature of the soil. At St. George's Colliery, which is the highest part of the township the following section was found:—

	Yds.	Ft.	In.
Till (No. 3)	15	0	0
Sand, Gravel, and Loam (No. 4)...	3	1	6
	18	1	6

Generally speaking (as before stated) the thickness of the Till in Manchester and its vicinity is pretty clearly ascertained by the height of that deposit above the level of the river Irwell; and it is very often found under No. 1, in the low

parts of the town. The only exception to this rule of estimating the thickness of the Till, to my knowledge, is a district lying between the Buck Inn, in Booth-street, and the south end of Essex-street. Near the first-named place the Till ought to be about ten yards in thickness, according to the height of the locality above the Irwell; but it is only about a yard. After going through the Till, the sand is reached, and afterwards beds of gravel occur. The two last-named deposits appear to occupy the position of No. 4, and may be considered as an extraordinary development of that deposit in the neighbourhood of Manchester—although Mr. William Lancaster informs me that in boring, at Barton Moss, he found under fifteen yards of Till, eight yards of sand and gravel. The excavations for the new Branch Bank of England, in King-street, showed the occurrence of the sand and gravel under the Till, and caused considerable difficulty in getting a foundation for that building. The following sketch will best explain the position of the deposits, *a* representing the Till and *b* the sand and gravel:—

Fig. I.



ARDWICK.

The surface of the south-eastern portion of this township, for the most part, consists of gravel No. 1. The tract, bounded by the river Medlock on the north, Chorlton-upon-Medlock on the west, and a line from near the bridge in Fairfield-street, round past the cemetery to the Polygon, on the south, comprising the most populous part of this township, is dry gravel, often resting on upper new red sandstone, having two or three feet of silty loam at the top. The south eastern part of the township, towards Openshaw, Longsight, and Victoria Park, consists of strong brick-clay (No. 3) of variable thickness. On the whole, the greater part of the houses in this suburb, being built on No. 1, must be considered as located upon a dry soil, which will much assist in the drainage of the water. In a section at Dibb-place, Victoria Park,* the following beds were met with :—

	Yds.	Ft.
Till	17	2
Sand and gravel	1	0
	18	2

* This place is not in the township of Ardwick, but the section will give a good idea of the deposits of the higher part of that township.

BRADFORD.

This township is upon No. 3, with the exception of a little strip of land in the valley of the Medlock, below the Phillips' Park, which consists of No. 1. The section at St. George's Colliery, before mentioned, will give a good idea of the Drift deposits in this township.

BESWICK.

The whole of this township is upon No. 3. At Mr. Williams's Fire Clay Pit the following section occurred :—

	Yds.	Ft.
Till	16	0
Sand	0	1
Gravel	1	1
	17	2

CHORLTON-UPON-MEDLOCK.

The area, bounded by the river Medlock, and Hulme on the south-west, Ardwick on the north-east, and a line drawn from the Polygon to the south-west corner of Greenheys Field, nearly the course of Cornbrook, is all upon gravel (No. 1),

but the ground to the south-east of that line, including the upper portion of Brook-street and Greenheys, is brick clay (No. 3). The following section was met with in Oxford-road, near the Town Hall :—

	Yds.	Ft.
Gravel and sand (No. 1) about	4	0
Till and No. 4 gravel, about	8	0
	12	0

HULME.

The whole of this township may be considered as being upon gravel No. 1, resting, in some places, on Till, and at other places on upper new red sandstone, affording fine dry land for building purposes. The greatest thickness of the Drift in this township, which has come to my knowledge, is near the New Church in Stretford New Road, where the gravel and Till reached sixteen yards. The loamy clay on the surface is about three to four feet thick, the sand and gravel under it varies from twelve to fifteen feet, and the Till and No. 4 from twenty to thirty feet. In the valley of the Medlock is an interesting deposit of later origin than any other alluded to in this paper, one evidently formed

by the present river. When the new gas pit was being excavated, in River-street, on its south side, a good deal of gravel (No. 1) was met with before the upper red sandstone rock was reached, but on its north side, just below Messrs. Birley and Co.'s Mackintosh works, a bed of silty clay occupied the place of the gravel, and the sandstone was not seen at so high a level. On the north side of the excavation, a fine oak tree was met with, having its under side embedded in blue clay, and its upper part covered with silt. It was about eleven yards in length, and measured two feet seven inches in diameter at its middle. The roots lay towards the south-west, and its top to the north-east, at a depth of twelve feet from the surface. The lower part of the trunk was decayed, and filled with silt, but its top was quite sound. Oak branches, and portions of pine and hazel were found lying beside the trunk. From all the appearances presented, it was evident that the place where the tree was found had once been the bed of the Medlock, and that the tree had either been brought into the position in which it was found by a flood, or, having been first undermined by the current of the river, it was

then precipitated into its bed, and subsequently buried in silt.

SALFORD.

The lower portions of this township, skirting the banks of the Irwell, from Broughton Bridge to the New Bailey Bridge, are either on the upper new red sandstone or on gravel (No. 1), but the higher parts of the town, about King-street, St. Stephen's-street, Shaw's-brow, Adelphi, the Crescent, Oldfield-lane, and the greater part of Regent-road and Cross-lane, are on brick-clay (No. 3). The whole of the flat tract of land lying in the valley of the Irwell, from below Ordsall Hall to Mode Wheel, is on No. 1. At Messrs. Ashton's, near Broughton Bridge, the following section occurred :—

	Yards.
Soil and clay, about	2
Quick-sand and gravel, Nos. 1 and 4 ?	12
	14

At Mr. Thomas Bury's, near the Adelphi Baths, the beds of Drift were as follows :—

	Yds.	Ft.	In.
Till	6	0	0
Sand and Gravel No. 4	10	1	6
	16	1	6

The Till about Cross-lane, according to the opinions of the well-sinkers who have been employed in the neighbourhood, varies from twenty-five to thirty yards in thickness.

PENDLETON.

The land near Windsor Bridge, as well as that adjoining Cross Lane, is brick-clay, (No. 3 ;) but all the higher parts of the township are composed of light dry sand, and fine gravel, (No. 2,) both admirably adapted for drainage ; whilst the lower part in the valley of the Irwell is composed of gravel (No. 1,) permeable by water.

At Mr. Fitzgerald's Balance Pit, in the valley of the Irwell, the following section was met with :—

	Yds.	Ft.	In.
Soil and Loam	2	0	0
Coarse Gravel	2	0	0
Fine Laminated Brown Clay (Book Leaves)	0	2	3
Till	6	0	0
Sand and Gravel	1	0	0
	11	2	3

This section proves that the Till underlies the deposit No. 1, in the valley of the Irwell below Pendleton. In sinking a well at the Industrial School, Swinton, a section of the higher part of the Drift was obtained, which although not in Pendleton, but an adjoining township, it is thought right to give :—

	Yds.	Ft.	In.
Dry Sand	4	0	0
Marl	1	0	0
Quicksand	9	0	0
Clay (Book Leaves)	1	2	0
Dry Sand	14	0	0
Marl, with Stones	2	0	0
	31	2	0

CHEETHAM.

The houses in Strangeways, on the flat part of land adjoining the Irwell, built on No. 1, form the only exception in the southern and midland portions of this township—comprehending Strangeways, Red Bank, Stocks and Cheetwood—to the thick deposit of brick-clay, (No. 3,) on which the greater number of the houses of this township are erected. All the district north of a line running a little south of a new street, below the

Zoological Gardens, through Temple Toll-bar to Smedley Vale, is upon fine sand, (No. 2.)

In cutting the new line of road from the end of Halliwell-lane to the New Bury Road, at the end of Broughton-lane, an interesting section, showing the relation of the sand, (No. 2,) to the Till, has been met with. In excavating the rising ground, about four hundred yards south of Halliwell-lane, after sinking through two or three feet of clay, twenty-one feet of fine sand, having thin seams of drifted coal in it, was met with; at the south end the clay thickened, and the sand could not be seen for a distance of about fifteen yards; after this interval the sand again appeared, and was seen gradually diminishing in thickness, and resting on the main deposit of Till into which it finally passed.

The general character of the subsoil of the thickly built portion of the township, with the exception of the low part of Strangeways, in the valley of the Irwell, which is chiefly on gravel, (No. 1,) is decidedly unfavourable to natural drainage. In the highest parts of the township in Cheetwood, and near Mount Pleasant, the Till is supposed to reach full twenty-five yards in thick-

ness. In sinking the foundation for the Leeds Railway Station, near the Workhouse, the following section was met with :*—

	Yds.	Ft.	In.
Till of a Bluish Colour	3	0	0
Ditto of a Brown Colour	0	2	0
Brown Gravel, resting on Upper New Red Sandstone	0	2	0
	4	1	0

CRUMPSALL.

The whole of the higher part of this township may be considered as being upon a very dry bed of sand (No. 2) most admirably adapted for drainage. As you proceed down to Lower Crumpsall the Till is met with on the hill-sides, coming out from under the sand ; and in the valley of the Irk is gravel, (No. 1.)

Mr. W. S. Williamson has been so good as to inform me that the sand (No. 2) was penetrated fifteen yards, in searching for water, by Mr. Andrew Mayor, near the 'Staff of Life' public house, in Cheetham Hill, without its entire thickness being proved.

* Strictly speaking, this is in the township of Manchester.

BROUGHTON.

The lower part of this township, in the valley of the Irwell, is situate on sand and gravel (No. 1,) and the higher and more northernly portions on fine sand (No. 2). The only place where the brick-clay (No. 3) occurs, is a strip of land running by the side of the Bury New Road, from the end of Broughton-lane to Mount Broughton, and extending over the rising ground about Stony Knolls. With this exception, the district is on a dry bottom, and well drained by the nature of its subsoils.

The following is a section of one of the highest hillocks on Kersal Moor :—

	Yds.	Ft.	In.
Sand and Gravel	1	0	0
Clay, with pebbles (Till)	0	2	6
Fine Sand, containing much drifted coal, upwards of......................	20	0	0
	21	2	6

The entire thickness of No. 2, on the highest parts of Kersal Moor, must amount to full twenty yards before the Till is reached. That the latter deposit does underlie the sand, is proved by the

strata met with in the valley, just below the moor, where Messrs. Bleackley, at their works, bored a considerable depth some years ago. The kindness of these gentlemen has enabled me to give the following section :—

	Yards.
Sand and Gravel	21
Till	26
New Red Sandstone	2
	30

The range of the deposits is entirely from my own personal observations, without having received assistance from surveyors, or parties engaged in sewering ; and, from the great extent of the space, thickly covered with buildings, examined, it cannot be expected to be particularly exact. It is given as an outline, and can only be completed by careful levelling of the whole district.

On the Structure of the Valleys and Brook Courses.

The valley of the Irwell (which is of much the greatest extent) will, on reference to the map and sections, show that it has been cut through the

elevated lands of Kersal and Broughton on the one side, and those of Pendleton on the other, composed of Nos. 2 and 3—and through the rising grounds of Manchester and Salford, composed of Nos. 3 and 4, into the upper new red sandstone rock; and that the latter has afterwards been, more or less, covered by No. 1, which extends over nearly the whole of Hulme, and the lower south-west portion of Salford.

The valley of the Irk between Crumpsall and Harpurhey, is cut through Nos. 2 and 3, into red sandstone, and between Collyhurst and Smedley into the coal-measures; and in Newtown and Cheetham, through No. 3, into the new red sandstone formation. As it enters Manchester by Long Millgate, to its junction with the valley of the Irwell, its sides towards the south and south-east, are composed of No. 1. Portions of this deposit are also met with in small patches in its northern part, below Crumpsall; but the main portion of the valley, as it approaches Manchester is almost without it. This is perhaps owing to the valley passing through hard rocks, and being so narrow as to form a gut, which would contract the currents of water that formerly flowed in it,

thereby increasing their force, and causing them to sweep the deposit out.

The valley of the Medlock in Bradford and Beswick, is through Nos. 3 and 4, into the coal measures; and in Ardwick, Chorlton, and Manchester, through the same deposits, into the upper new red sandstone. The beds of gravel and sand found in Ardwick, Chorlton-on-Medlock, and Hulme, like those of the Irk, appear to have been swept out of the upper part of the valley of the Medlock, but some of them may have been derived from the Irwell. By looking at the map, it will at once be seen that the deposit No. 1, extends much further on the eastern than on the western side of the present river courses. All these three valleys bear evidence of having been formed under the sea, for the action of the present streams of water which now flow in them, appears to be unequal to produce the effects observed in any moderate period of time.

The small valleys in which the Cheetham brooks, Shooters-brook, and Corn-brook flow, are all cut through No. 3, and contain little (if any) of deposit No. 1, until they reach the larger valleys.

On every side of the towns of Manchester and Salford, we find "the Till," which can be pretty well traced by the numerous brick yards upon it, on the gently rising grounds adjoining the valleys, and in most parts where the ground rises to a considerable elevation, this deposit is capped by beds of sand and gravel. Thus the brick clay of Windsor Bridge is capped by the sands of Pendleton; those of Stony Knolls, Cheetham, and Collyhurst, by the sands of Higher Broughton, Cheetham Hill, and Harpurhey. The Manchester and Leeds Railway, after passing through the Till of Moston, and reaching the higher land south of the Middleton Station, cuts through sand. The Sheffield and Ashton line, after cutting through the Till of Gorton, reaches the sand of Fairfield; the Birmingham line, after reaching a certain elevation at Levenshulme, between Manchester and Stockport, cuts through a similar deposit. A portion of Till is also frequently found in the valleys lying under the sand and gravel No. 1, as proved in the section of Mr. Fitzgerald's pit, before alluded to, which shows that portions of it have been removed by currents of water during the formation of the valleys.

On the Composition of the Till.

The phenomena presented by the different beds of gravel and sand forming deposits Nos. 1, 2, and 4, are so like the effects we now observe being produced on the beaches, strands, and water-courses, at the present time, that we can have no doubt as to the manner in which they were formed, any more than of the origin of the shingle beds and sand banks of our coasts. The pebbles contained in them are rounded, and have nearly all lost their angles by attrition, and none of them, to my knowledge, have been met with having their surfaces scored with *striæ*. These deposits are, in point of fact, nothing more than raised beaches and old sand-banks, cut through by currents of water, which formed the valleys before and during the time of their elevation. The Till however is a deposit very different in its characters to any that we now see being formed; for while its clay and its finely laminated beds of silt would seem to show that it was deposited in still water, the great and small blocks of stone scattered throughout its mass pell-mell, would lead us to believe that violent currents had been in action at the same time that the clay and silt were

being deposited. In former papers this deposit was described, but not with sufficient detail. It is well known as a brownish-coloured stiff clay containing generally about thirty-six per cent of alumina, mixed with variable proportions of sand and carbonate of lime. It effervesces freely when treated with acids.

A series of correct analyses of it is much wanted, and the above statement of its composition is given only as an approximation to truth. As the rocks found in the Till are the most interesting portions of the deposit, considerable attention has been paid by me to them, in order to ascertain their natures, and their external characters. For this purpose one hundred specimens of rocks have been taken from three different brick yards, and after examination the results are given in the following table :—

TABLE OF ROCKS FROM THE TILL NEAR MANCHESTER.

	Regent-Rd Salford.		Cheetham.		Openshaw.		Mean.	
	Per Cent.		Per Cent.		Per Cent.			
Granites, Greenstones, and other igneous rocks		21		15		27		21
Angular	3		5		7		5	
Partly rounded	12		7		11		10	
Rounded	6		3		9		6	
Slates and Silurian Rocks		19		27		17		21
Angular	3		4		4		3.66	
Partly rounded	11		8		8		9	
Rounded	5		15		5		8.33	
Mountain Limestones		5		6		7		6
Angular	1		2		0		1	
Partly rounded	3		2		4		3	
Rounded	1		2		3		2	
Coal Measures		49		50		49		49.33
Angular	22		31		23		25.33	
Partly rounded	21		16		20		19	
Rounded	6		3		6		5	
New Red Sandstones		6		2		0		2.66
Angular	4		2		0		2	
Partly rounded	2		0		0		0.66	
Rounded	0		0		0		0	
		100		100		100		100
Striated Rocks		2		2		1		1.66

The stones from Openshaw are from the east, those of Strangeways from the north, and those of Regent Road, near the Infantry Barracks, from the west of Manchester ; so the mean of the three will give a fair average of the rocks found in

this deposit, and their present external characters. The specimens were not selected out of the clay, but were picked up promiscuously from the stones thrown out by workmen when they were digging the clay during winter. All the rocks are found *in situ* to the north and north-west of Manchester.

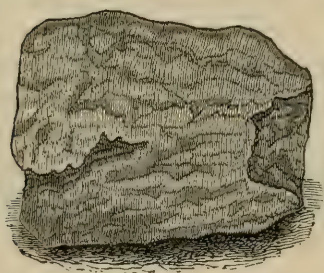
On the Large Boulders found in the Till.

These are well known in the neighbourhood of Manchester, and are generally found dispersed throughout the deposit. They are both more numerous and of much larger size in some localities than in others. Thus, for instance, on the rising ground above Broughton Spout, and at Park Place, Stony Knolls, and near the Vauxhall Gardens, Collyhurst, larger than average specimens have been met with.

The following are the largest and most interesting blocks that have come under my observation. A piece of hard Greenstone, showing many *striæ*, having most of its sides angular, but one smoothed, weighing near a ton, and now lying on the new road above the house lately occupied by Mr. Thomas Swallow.

About two hundred yards from the last described specimen, near Mr. Wm. Sale's house, there is a large block of Ravenglass Granite, (Fig. 2,) measuring seventeen feet one inch in circumference, and about four feet high. It has lost most of its edges, but there are some portions of it which appear to have suffered less from attrition than others.

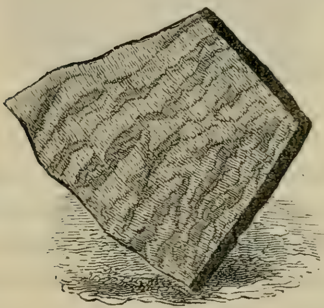
Fig. 2.



Not far from the last stone, and a little nearer Manchester, is seen a flag of Sandstone, (Fig. 3,) belonging to the upper part of the coal measures. It appears nearly as perfect as if it had been but just taken from the quarry, having lost none of its edges. It has four unequal sides, measuring

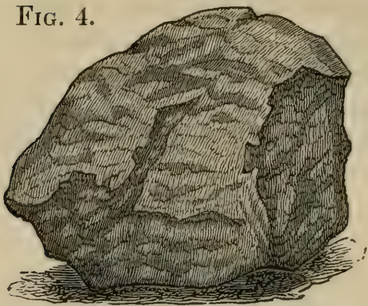
respectively 3 feet 10 inches, 3 feet 8 inches, 5 feet 6 inches, and 6 feet 3 inches, and is 1 foot 2 inches in thickness.

Fig. 3.



Near the road leading up to the inn adjoining the Vauxhall Gardens, is a well-rounded block of Greenstone, weighing about three tons. Above Mr. Edmund Buckley's Sand Delph, not far from the last described stone, is a fragment of Millstone Grit, (Fig. 4,) partly angular and partly smoothed, measuring 4 feet 2 inches high, and 18 feet 8 inches in circumference, being the largest block that, to my knowledge, has been met with in the neighbourhood of Manchester.

FIG. 4.



By the side of Upper Brook-street, at the corner of Hughes-street, was formerly seen a large block of Trap Rock, having some of its sides smoothed, and others rugged. Besides the above, there are no doubt many others of less magnitude which have escaped observation.

ON THE ORIGIN OF THE TILL.

When the whole of the Drift phenomena were summarily disposed of by attributing them to the Noachian deluge, little attention had been paid to this deposit, or else its formation could not have been attributed to the same cause that produced the beds of sand and gravel. The action of waves on lines of rocky coast, and the effects now caused by running water, clearly show us how

rounded pebbles have been produced, and we are not now reduced to the strait which the learned author of "Natural Theology," Dr. Paley, was, when in the first chapter of his book he says, "In crossing a heath, suppose I pitched my foot against a stone, and were asked how the stone came there, I might possibly answer, that for anything I knew to the contrary, it had lain there for ever; nor would it perhaps be very easy to show the absurdity of this answer."

At the present day, to most geologists the stone on the heath would tell its own simple story. If its sides were angular, and rocks of a similar character were located in the neighbourhood, it would be pretty clear that it was a native of the district, and had not travelled from afar. But if its angles had all been removed, and it was a rounded pebble of a description of rock not found *in situ* within many miles, then would it tell of its travel by flood, and how it had undergone the buffeting of the waves, and the jostling of its neighbour stones. Should, however, it be composed of iron, nickel and cobalt, in the proportions usually met with in meteorites, it would be supposed to have come *through* the atmosphere, but from whence it is difficult to say.

The effects of large rivers carrying with them the *debris* of the land flowing into estuaries, clearly indicate the origin of sand banks; and the power of mountain streams to move vast masses of rock, when once put in motion, is now well known; but all these agencies are insufficient to account for the phenomena which are observed in the Till; for where do we see a current of water that, at the same time and place, will deposit beds of fine laminated silt, and homogeneous clay, with immense masses of rock, blocks of the same kind of stone, some of which are perfectly rounded, others smoothed only on one side, having the rest of their sides quite rugged, others perfectly angular, and others again grooved or marked with *striæ?* Such different effects cannot rationally be attributed to one cause. Latterly the action of glaciers and icebergs has been called in to assist us in our enquiries; and it is probably to the conjoint action of these powerful agents and currents of water, that we must look to for the origin of the deposit of Till in the neighbourhood of Manchester.

In my former paper on Drift,* it was shown that

* Published in the Report of the Manchester Geological Society, for 1843.

portions of that deposit are now to be met with in Lancashire and Cheshire at elevations of from one thousand to twelve hundred feet above the present level of the Irish sea, and, consequently, that there must have been great changes in the contour of the country, probably even such as to allow of a glacier extending from the lake districts to Manchester; still, it is most certain, that the Till in our neighbourhood does not present us with phenomena such as now are produced either by lateral or terminal *moraines*. The distribution of the rocks in the clay, the deposit of the clay itself, and, above all, the beds of fine laminated silt seen in the Till at Collyhurst, and other places, consisting of layers thinner than the paper upon which this is printed, and from this circumstance provincially termed *book leaves*, seem to indicate that the rocks were conveyed to the places where they are now found on icebergs, and then deposited in the soft mud, now clay, at the bottom of a sea; while the partly rounded and scored rocks belonging to the North of Lancashire and the lake district, seem to point out the effects of glaciers—not, probably, such as are now seen in the Alps, but like those of Spitzbergen, which extend to the ocean, and of which vast icebergs are the offsprings.

Concluding Remarks.

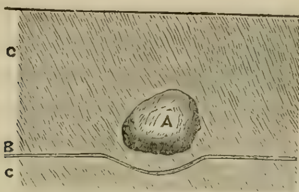
The deposit No. 1 bears every appearance of having been formed by an ordinary current of water. It was most probably caused by the subsidence of the land beneath the waters of the sea in which the Till was deposited. The rocks found in this deposit, as well as those in No. 2, are the same as those found in the Till, but nearly all of them have lost their angles, and appear water-worn.

If my opinion, as to the beds of Till having been partly formed by the stranding and dissolving of icebergs, is true, the neighbourhood of Manchester was once the bottom of a deep sea, in the waters of which floated immense masses of ice, freighted with blocks of stone. That these icebergs drifted about until some of them were were melted, or arrested in their course by the higher lands of Broughton and Collyhurst, then forming sunken rocks, and it is to these circumstances most probably that we owe the greater number of large stones now found in the Till at those places.

In the bed of Till at Collyhurst, the large block

of millstone grit, before mentioned, was found embedded. About three feet under this stone, the bed of silt exhibited a bend, as shown in Fig. 5, just as if the stone had fallen from above, and thus caused the curvature of the silt.

FIG. 5.



A—A Block of Stone.
B—A Bed of fine laminated Silt.
C—Homogeneous Till.

Probably this one fact is not of itself sufficient to show that the stone had been precipitated from a melted iceberg, but, by careful examination of the deposit in other places, more examples of this character may, perhaps, be found to confirm it.

Many of the scored and polished rocks may owe their *marked* characters to the grinding and crushing effects of floating fields of ice, which would cause nearly similar appearances on rocks to those produced by the motion of glaciers. On the ele-

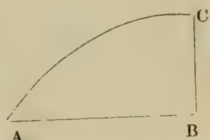
vation of the land, and consequent shoaling of the sea, the icebergs would cease to enter the latter, but strong currents of water, probably produced by the dissolving of neighbouring glaciers and other causes, brought down the beds of sand and gravel (No. 2,) and covered up the Till. On the land continuing to rise, these sand banks would be more exposed to the action of the currents, owing to the waters becoming shallower, and then the valleys and undulations now seen in this neighbourhood would be formed by currents cutting through Nos. 2, 3, and 4, and removing portions of those deposits, so as to form the gravels and sands No. 1. Similar effects, on a small scale, may now be seen taking place in the sand banks of our present coast, on the recession of the tide, where numerous little valleys are excavated, and slight deposits of gravel deposited on their sides and at their extremities. No doubt the action of the streams of water at present flowing in the valleys may have, in some measure, assisted to excavate them ; but by far the greater part of the erosion has been done when this part of the country was under the sea.

V.—*A New Mode of Representing Discontinuous Functions.* By Mr. Robt. Rawson.

(Read February 10th, 1846.)

1. Mathematical discontinuity may be explained in the following manner:

Fig. 1.

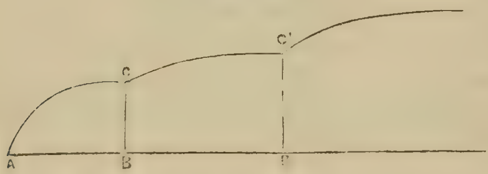


Let AC, Fig 1, represent any curved line, and from A draw the straight line AB in any direction, upon AB demit the perpendicular BC. Now, if $AB = x$ and $BC = y$, the relation which exists between x and y is called the equation of the curved line AC; x is generally taken for the independent variable, and y the dependent variable, which is said to be some explicit or implicit function of x, either algebraical or transcendental; this function is usually expressed in the following manner:

$y = f(x)$, for explicit functions of x ......(1).
$f(y, x) = 0$ for implicit functions of x ...(2).

This convenient and powerful notation was first used, I believe, by Lagrange, whose powers, to create symmetrical symbols designed to represent groups of ideas, were almost unlimited.

FIG. 2.



(2). If, as in Fig. 2, when x becomes equal to $AB = a$, the function of x be changed to some other function of x represented by $f_1(x)$; and when x becomes equal $AB^1 = b$, the function of x be changed to $f_2(x)$; and so on, that is, if we take

$$y = f(x);\ y = f_1(x);\ y = f_2(x) \text{ \&c. \&c.}$$

the first to exist for all values of x between the limits $x = o$ and $x = a$; the second to exist for all values of x between the limits $x = a$ and $x = b$; the third between the limits $x = b$ and $x = c$, &c. &c. Then these functions are denominated by

mathematicians discontinuous functions, and the points C, C^1 &c. are called breaks. The object of the following researches is to express, by means of one equation, the relation of the system of lines generated by these discontinuous functions.

(3). In the above exposition of discontinuity, the independent variable is supposed to be continuous, or to admit of every magnitude between the limits $x = o$ and $x = a$. If the independent variable be allowed to take only particular values between the limits $x = o$ and $x = a$, &c. &c. another species of discontinuity will be brought into operation, a particular case of which will lead us to the calculus of finite differences.

(4). The following analytical explanation of these different variations will tend to place the subject in a clearer point of view.

Let $y = f(x)$; If we suppose x to take an increment h, and the function to remain constant, we shall have, by putting y' to represent the corresponding increment of the function,

$$y' = f(x+h) = f(x) + \frac{f'(x).}{1} h + \frac{f''(x)}{1.2} \cdot h^2 + \&c. \&c.$$

Then, $y' - y = \frac{f'(x)}{1} \cdot h + \frac{f''(x)}{1.2} \cdot h^2 + \&c. \&c.$

or, $\frac{y' - y}{h} = \frac{f'(x)}{1} + \frac{f''(x)}{1.2} \cdot h + \frac{f'''(x)}{1.2.3} \cdot h^2 + \&c. \&c.$

Now, if h takes only the values 1, 2, 3, 4, &c. &c. between the limits $x = o$ and $x = a$, or the increment of x be equal to unity; then, it is the object of the calculus of finite differences to calculate, in every possible function of x, the value of $y' - y$.

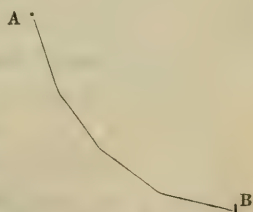
But, if h takes every value between the limits $x = o$ and $x = a$, or the increment of x be equal to nothing; then, it is the object of the differential calculus to calculate in every function of x the value of $\frac{y' - y}{h}$, when $h = o$.

Hence, by referring to (Art. 2), we shall readily see, that if the curve ACC′ be generated by a law which is invariable, and a, b, c, &c. &c. be taken equal to 1, 2, 3, &c. &c. respectively, we shall then have a variation which corresponds to the calculus of finite differences.

(5). If we suppose x to take every magnitude

between given limits, and the function of x to vary from one function to another, during the variation of x, so that no function of x shall correspond to two values of x, however near to each other; we shall then have a species of variation which corresponds to the calculus of variations, an example of which was first given by Sir I. Newton, in the Principia, book 2, prob. 34.

(6). If we suppose the function of x to vary, while x takes the values 1, 2, 3, &c. we shall have a species of variation which might be, with propriety, denominated the variation of the calculus of finite differences. Many instances of the application of such a calculus might be given, one of which is the following:



Let A and B be two points not in the same vertical line; and suppose a material body to move from A to B, by the force of gravity, along n inclined planes, the length of each being a; Required the position of the planes when the material body moves from A to B in the least time possible?

If Σ and Δ in the calculus of finite differences, correspond with $\int$ and d in the differential calculus; the difficulties which will have to be overcome to establish such a calculus as the one above mentioned, may be shown to some extent by the following considerations:

Suppose, for instance, $y = \Sigma_a^b . \mathrm{f}(x) \Delta x$, where $\mathrm{f}(x)$ is some unknown function of x, which must be determined before the value of y can be obtained. But if the object of the inquiry were to determine the unknown function of x, such that the value of y must satisfy one or two conditions given by the particular nature of the inquiry—It would then be the object of such a calculus of the variations of finite differences, which I have ventured to suggest, to determine the unknown function of x. The principles of this calculus have not, to the best of my knowledge, been given, nor has the existence of such a calculus ever been pointed out, or a particular question been proposed, requiring its assistance, before the one above given.

(7). By referring to Fig. 2; and putting $AB = a$, $AB' = b$, $AB'' = c$, &c. &c. And take

Y to represent any ordinate, parallel to the axis of y, of the system of lines above described. Then we shall have

$$Y = \Phi (a, b, c.........x)..................(1)$$

Where $\phi (a, b, c.......x)$ must be such a function of $(a, b, c.......x)$ as will satisfy the following conditions.

$$Y = f(x) \text{ ; when } x < a, \text{ and greater than } o$$
$$Y = f_1(x) \text{ ; when } x < b, \text{ and greater than } a$$
$$Y = f_2(x) \text{ ; when } x < c, \text{ and greater than } b$$
$$\&c. \qquad \&c. \qquad \&c.$$
$$Y = f_{n-1}(x) \text{ when } x < \beta, \text{ and greater than } \beta_1$$

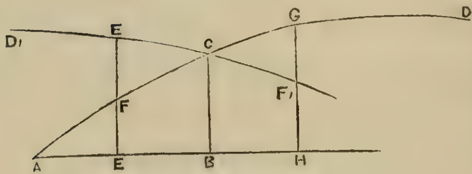
The means by which these conditions have been, hitherto, fulfilled are, either by the aid of definite integrals, or by infinite series. See Dr. Peacock's report on certain branches of analysis, British Association, 1833, page 250, where he has given a review of what has been done in this important branch of analysis.

Required to determine the equation of a system of lines containing one break.

(8). Adopting the same notation as in Art. (7) we shall have

$$Y = f(x), \text{ when } x < a, \text{ and greater than } o -$$
$$Y = f_1(x), \text{ when } x > a$$

FIG. 3.



Let the discontinuous curves AC, CP, Fig. 3, be produced, from the point of intersection C, to the points D and D_1 respectively. Draw FPE, GP_1H perpendicular to AB—it will readily be seen that, for every value of x on the axis AB, there will be two values of the ordinate, viz.: PE and FE; except in the particular case when $x = a$. For when $x =$ AE, we have the corresponding ordinates EP and EF, the first of which refers to the curve AC, whose equation is $y = f(x)$ and the second refers to the curve CP_1 whose equation is $y = f_1(x)$. If we take $x =$ AH we shall have in the same manner two values of the ordinate, viz.: GH and P_1H. It appears from the above considerations, that the value of Y must partake of the nature of a quadratic equation, or

be of such a form that the signs of operation will be sufficient to give the two values of Y. This condition will be satisfied by the following artifice:

$$2\,\mathrm{Y} = \mathrm{f}(x) + \mathrm{f}_1(x) \pm \left\{\mathrm{f}(x) - \mathrm{f}_1(x)\right\} \ldots\ldots\ldots\ldots (1)$$

where + is to be taken when x is less than a, and − when x is greater than a. Therefore, the above equation may be written in the following manner:

$$2\,\mathrm{Y} = \mathrm{f}(x) + \mathrm{f}_1(x) + \Phi_1(a, x)\left\{\mathrm{f}(x) - \mathrm{f}(x)\right\} \ldots\ldots\ldots (2).$$

where $\Phi_1(a, x)$ must be such a function of (a, x) as will satisfy the conditions, that when x is less than a we must have $\Phi_1(a, x) = 1$. and when x is greater than a, we must have $\Phi_1(a, x) = -1$.

In searching through the wide field of functional analysis, various functions of (a, x) may possibly be found, that will satisfy the conditions which the above considerations have imposed upon them; none more simple, perhaps, than the following:

$\Phi_1(a, x) = \frac{a - x}{a \backsim x}$, which will satisfy the conditions of the problem, and equation (2) will become,

$$2\,Y = f(x) + f_1(x) + \frac{a - x}{a \backsim x}\left\{f(x) - f_1(x)\right\}$$

$$= \left(1 + \frac{a - x}{a \backsim x}\right) f(x) + \left(1 - \frac{a - x}{a \backsim x}\right) f_1(x) \;\ldots\ldots(3).$$

so that, whatever value is given to x, this formula, which is called the equation to the system, will give the corresponding value of Y.

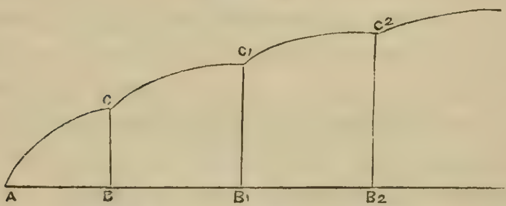
(9). The function $\frac{a - x}{a \backsim x}$, expressing the remarkable property above stated, may possibly lead to some interesting results in the application of analysis to geometry; in consequence of this we shall call it the operative function.

The quantity $a \backsim x$ is necessarily a positive quantity, without any consideration as to which of the two quantities a or x exceeds the other. The signs plus and minus, denote operations the reverse of each other, and when they are used in

this sense they become perfectly intelligible; thus $a + b$ generally denotes, that whatever may be the interpretation of the quantities represented by the symbols a and b; the quantity represented by a must be added to the quantity represented by b. The analyst, in accordance with his general views, attaches another idea to the symbols $a + b$; he no longer regards $a + b$ as denoting an operation, but considers the quantity thus symbolized as a simple one, upon which he may perform other operations to aid him in his investigations. The same remark will equally apply to the other signs of operations $(a - b)$, ab, $\frac{a}{b}$, to each of which we may attach the general idea of abstract magnitude, besides that of their common intepretation. Now, the $\backsim$ placed between two quantities denotes their difference, and is quite distinct from either of the signs of operation $+$ and $-$; since it does not denote any operation, but simply an abstract quantity, which is, the quantity that one magnitude exceeds that of another. The operations denoted by $+$ and $-$ have an equal power to assist us in obtaining the value $a \backsim x$, which represents $(a - x)$ when $a > x$, and $(-a + x)$ when $a < x$.

Let it be required to determine the equation to the system of lines containing any number of breaks, as in Fig. (4).

FIG. 4.



(10). Put $AB = a$; $AB_1 = b$; $AB_2 = c$, &c.

Observing the same notation as before, with this difference, that,

$Y_1 =$	the ordinate to the system with one break		
$Y_2 =$	Do.	Do.	two breaks
$Y_3 =$	Do.	Do.	three breaks
&c.	&c.		&c.
$Y_n =$	Do.	Do.	n breaks

Now, if we take for simplicity

$$1 + \frac{a - x}{a \backsim x} = A \text{ .... and } 1 - \frac{a - x}{a \backsim x} = A_1$$

$$1 + \frac{b - x}{b \backsim x} = B \text{ .... and } 1 - \frac{b - x}{b \backsim x} = B_1$$

$$1 + \frac{c - x}{c \backsim x} = \mathrm{C} \text{ .... and } 1 - \frac{c - x}{c \backsim x} = \mathrm{C}_1$$

And generally,

$$1 + \frac{\beta - x}{\beta \backsim x} = \Psi \text{ .... and } 1 - \frac{\beta - x}{\beta \backsim x} = \Psi_1$$

we shall have from equation (3) Art. 8.

$\mathrm{Y}_1 = \dfrac{\mathrm{A} \cdot \mathrm{f}(x)}{2} + \dfrac{\mathrm{A}_1 \cdot \mathrm{f}_1(x)}{2}$, for the system containing one break.

$\mathrm{Y}_2 = \dfrac{\mathrm{B} \cdot \Phi(x)}{2} + \dfrac{\mathrm{B}_1 \mathrm{f}_2(x)}{2}$, for the system containing two breaks.

$\mathrm{Y}_3 = \dfrac{\mathrm{C} \cdot \Phi_1(x)}{2} + \dfrac{\mathrm{C}_1 \cdot \mathrm{f}_3(x)}{2}$, for the system containing three breaks.

&c. &c. &c.

$\mathrm{Y}_n = \dfrac{\Psi\, \Phi_{n-1}(x)}{2} + \dfrac{\Psi_1\, \mathrm{f}_n(x)}{2}$, for the system containing n breaks. Where

$$\Phi(x) = \mathrm{Y}_1, \text{ and } \Phi_1(x) = \mathrm{Y}_2, \text{ and } \Phi_2(x) = \mathrm{Y}_3 \ldots \Phi_{n-1}(x) = \mathrm{Y}_n$$

Now, if we substitute these values of $\phi(x)$ &c. in the above equations we shall obtain the ordinate of the system, parallel to the axis of y, in functions of the independent variable x in the following manner:

$$Y_1 = \frac{A \cdot f(x)}{2} + \frac{A_1 \cdot f(x)}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$Y_2 = \frac{A \cdot B}{2.2} . f(x) + \frac{A_1 B}{2.2} . f_1(x) + \frac{B_1}{2} . f_2(x) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$Y_3 = \frac{A \cdot B \cdot C}{2.2.2} . f(x) + \frac{A_1 \cdot B \cdot C}{2.2.2} . f_1(x) + \frac{B_1 \cdot C}{2.2} . f_2(x) + \frac{C_1}{2} . f_3(x) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$Y_4 = \frac{A \cdot B \cdot C \cdot D}{2.2.2.2} . f(x) + \frac{A_1 \cdot B \cdot C \cdot D}{2.2.2.2} . f_1(x) + \frac{B_1 \cdot C \cdot D}{2.2.2} . f_2(x) + \frac{C_1 \cdot D}{2.2} . f_3(x) + \frac{D_1}{2} . f_4(x) \quad \ldots\ldots\ldots\ldots \quad (4)$$

&c. &c. &c.

$$Y_n = \frac{\cdot A \cdot B \cdot C \ldots\ldots \Psi}{2^n} . f(x) + \frac{A_1 \cdot B \cdot C \ldots\ldots \Psi}{2^n} . f_1(x) + \frac{B_1 \cdot C \ldots\ldots \Psi}{2^{n-1}} . f_2(x) + \frac{\ldots\ldots \Psi_1}{2} . f_n(x) \quad \ldots\ldots\ldots \quad (5)$$

These formulæ will be found to be applicable to the determination of any lines connected with these discontinuous curves; such for instance, to find the tangent, radius of curvature, &c. &c. without having recourse to infinite series, or to their equivalents, definite integrals.

It must be remembered, however, that the connexion of the system will give us the following relations amongst the functions, viz.:

$$\mathrm{f}(a) = \mathrm{f}_1(a);\ \mathrm{f}_1(b) = \mathrm{f}_2(b);\ \mathrm{f}_2(c) = \mathrm{f}_3(c), \text{ \&c. \&c.} \ldots\ldots\ldots (6)$$

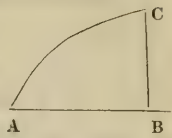
These equations will enable us to calculate the two tangents which may be drawn to each of the points C; C_1; C_2; &c. &c.; as it is evident there will be one tangent arising from the equation $y = \mathrm{f}(x)$, and another from the equation $\mathrm{f}_1(x)$, and this will obtain at all the other breaks of the system.

(11). If the relations $\mathrm{f}'(a) = \mathrm{f}_1'(a)$; $\mathrm{f}_1'(b) = \mathrm{f}_2'(b)$; $\mathrm{f}_2'(c) = \mathrm{f}_3'(c)$ &c. &c. exist, where $\mathrm{f}'(a)$ &c. &c. are the differential coefficients of $\mathrm{f}(x)$ &c. when $x = a$ &c. then the tangents at the points C; &c. &c. will coincide. This relation amongst the variable function of x which generates the discontinuous curve, will, I conceive,

be found to be of considerable application in the investigations in physical science.

(12). Hitherto, so far as I am acquainted with mathematical science, the object of mathematicians has been to investigate the locus of the extremity of the dependent co-ordinate, when the relation between the independent and dependent co-ordinates remains the same—or which is the same thing, to examine the infinite variety of solutions in a stream of continuous sequences, which may be given to an indeterminate equation between two variable quantities. This inquiry originated with the illustrious Descartes, in his successful attempt to solve the well known problem of the ancient geometers; and no advance, so far as I know, on this idea has been taken by any succeeding mathematician. We think the inquiry ought not to rest here; and would beg to suggest, to those interested in mathematical speculations, that it would be desirable to investigate, not only the infinite number of solutions of one indeterminate equation, but one or more solutions of an infinite number of indeterminate equations. To exemply this idea, it appears necessary to have recourse to the ordinary geometrical mode of representing the solutions of indeterminate equations.

FIG. 5.



Let AC Fig. (5) represent the solutions of the indeterminate equation $y = f(x)$ for every value of x between the limits $x = o$ and $x = AB$. This corresponds with Descartes' view of the subject, and supposes the function of x to remain the same for every value of x. Now, if we suppose the function of x, namely $f(x)$, to vary for every value of x between the limits $x = o$ and $x = AB$. The examination of the solution of each function for one or more values of x between the limits assigned above, is what I have ventured to suggest in the former part of this article.

(13). In most physical researches, the great object has been hitherto to discover a constant law that will connect the effects which are observed with the cause assigned to produce them. Those only who have tried properly know the difficulty of these speculations; and the few who have succeeded in their attempts to give a constant law connecting natural phenomena with their causes appear, to me at least, to have been successful only between assignable limits.

Required to determine the tangent to the system of lines containing any number of breaks, as in Fig. 4.

(14). If Y' and x' represent the co-ordinates of any point in the system of discontinuous curves; and y and x represent the rectangular co-ordinates of any point in the tangent to the point Y' x'; and T the tangent of the angle which the tangent to the curve makes with the axis of x,

Then we shall have,

$$y - Y' = T\,(x - x') \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1).$$

See Gregory's examples on the differential and integral calculus, page 142.

We have now to determine the value of T for any point in the curve.

By referring to art (10) we have $\frac{d\,Y_n}{d\,x} = T$

Hence, $d\,Y^n = d\left\{\frac{A{\cdot}B{\cdot}C \ldots \Psi}{2^n}\,.\,f(x) + \frac{A_1{\cdot}B{\cdot}C \ldots \Psi}{2^n}\,.\right.$

$\left.f_1(x) + \frac{B_1{\cdot}C \ldots \Psi}{2^{n-1}}\,.\,f_2(x) + \ldots \frac{\Psi_1}{2}\,.\,f_n(x)\right\}$

Since A, B, C, &c. &c. are functions of x, we differentiate under this hypothesis.

From Art. 10. we have $A = 1 + \frac{a - x}{a \backsim x}$ $\therefore d\,A$

$$= d . \frac{a - x}{d \backsim x} = - \frac{(a \backsim x)\, dx + (a - x) \frac{a - x)}{a \backsim x} . dx}{(a \backsim x)^2}$$

$\therefore \frac{d\,A}{dx} = - \frac{(a \backsim x)}{(a - x)} + \frac{a \backsim x}{(a \backsim x)^2} = 0$. since $(a - x)^2 = (a \backsim x)^2$.

In a similar way we have $\frac{d\,B}{dx} = 0$ and $\frac{d\,C}{dx} = 0$ &c. Consequently we shall have

$$\frac{d\,Y_n}{dx} = \frac{A \cdot B \cdot C \ldots \Upsilon}{2^n} . f'(x) + \frac{A_1 \cdot B \cdot C \ldots \Upsilon}{2^n} . f_1'(x) + \frac{B_1 \cdot C \ldots \Upsilon}{2^{n-1}} . f_2'(x) + \ldots \frac{\Upsilon}{2} f_n'(x)$$

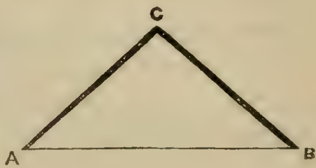
Hence, equation (1) becomes

$$\left(y - \overset{1}{Y} \right) = \frac{d\,Y_n}{d\,x} \left(x - x' \right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

(15). We shall now proceed to illustrate the above general formulæ, by the application of them to a few examples.

Determine the equation to the line ACB where AC and CB are the sides of an isosceles triangle.

Taking the point A for the origin of co-ordinates, and calling the hypothenuse AB = 2



We have for the equation of AC, $y = x$

Do. BC, $y = 2 - x$

Therefore, we have

$$y = x, \text{ between the limits } x = 0 \text{ and } x = 1$$

and

$$y = 2 - x, \text{ between the limits } x = 1 \text{ and } x = 2$$

consequently,

$$a = 1 \text{ and } f(x) = x \text{ and } f_1(x) = 2 - x$$

Substitute these values in equation (1) art. 10, and we shall have—

$$Y_1 = \left(1 + \frac{1-x}{1 \backsim x}\right)\frac{x}{2} + \left(1 - \frac{1-x}{1 \backsim x}\right)\left(1 - \frac{x}{2}\right)$$

$$= \frac{x}{2} + \left(\frac{1-x}{1 \backsim x}\right)\frac{x}{2} + 1 - \frac{x}{2} - \frac{1-x}{1 \backsim x} + \left(\frac{1-x}{1 \backsim x}\right)\frac{x}{2}$$

$$= 1 - \frac{1-x}{1 \backsim x} + \left(\frac{1-x}{1 \backsim x}.\right)x$$

$$= 1 - \frac{1}{1 \backsim x} + \frac{x}{1 \backsim x} + \frac{x}{1 \backsim x} - \frac{x^2}{1 \backsim x}$$

$$= 1 - \left(\frac{1 - 2x + x^2}{1 \backsim x}\right)$$

$$= 1 - \frac{(1-x)^2}{1 \backsim x}$$

Hence, $1 - \frac{(1-x)^2}{1 \backsim x}$ is the function of x, which expresses the relation of the two co-ordinates at any point from A to B. The quantity $1 \backsim x$ in the above equation expressing the relation between the co-ordinates, apprize us at once that the function of x, and, consequently, the value of y, undergoes a complete change when x arrives at unity. This value of Y may be used for all purposes respecting the division of the triangle ACB: thus, if it were required to find the area

we should only have to integrate $Y_1 dx$, between the limits $x = 0$ and $x = 2$.

$$\therefore \int_0^2 Y_1\, dx = \int_0^2 dx - \int_0^2 \frac{(1 - x)^2}{1 \backsim x}\, dx.$$

$$= 2 - \int_0^1 (1 - x)\, dx - \int_1^2 (1 - x)\, dx$$

$$= 2 - 1 + \frac{1}{2} - 1 + \frac{1}{2}$$

$$= 1, \text{ the required area.}$$

These forms of definite integrals can, by proper substitutions, be reduced to uniform limits.

The above example has been taken from a memoir on the Inverse method of Definite Integrals, communicated to the Cambridge Philosophical Society, by the late Rev. Robert Murphy, B.A. It is impossible to mention this great mathematician's name without feelings of deep regret, that he was cut off from his investigations at such an early period of his life. In looking over the long list of distinguished names that the University of Cambridge has produced since the

change which was principally effected by the labours of the celebrated Professor Woodhouse, we feel convinced that our continental neighbours will not much longer have to boast, over the country which gave birth to the immortal Principia, in almost every department of abstract science. In proof of this we need only advert to the recent struggle for the greatest astronomical discovery which has ever been made, taking into consideration the circumstances by means of which it has been effected.

(16). Suppose the earth to be a hollow sphere, it is known that the attraction of a spherical shell upon a point outside of the shell is proportional to $\frac{1}{x^2}$; and when the point is in the shell, the attraction is proportional to x; and when the point is in the inside of the shell the attraction is nothing.

Let a and b be the distances of the shell to the inside and outside respectively; x equal to the distance from the centre to the attracted point, and Y equal to the attraction.

We must have $Y = 0$, when $x < a$; and Y

L 1

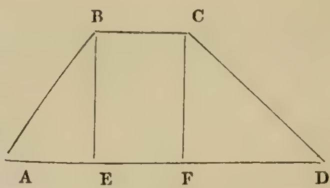
$= x$, when $x > a$ and less than b; and $Y = \frac{1}{x^2}$ when $x > b$, consequently $f(x) = 0$; $f_1(x) = x$; $f_2(x) = \frac{1}{x^2}$

$$\therefore Y = \left(1 - \frac{a - x}{a \backsim x}\right)\left(1 + \frac{b - x}{b \backsim x}\right)\frac{x}{4} + \left(1 - \frac{b - x}{b \backsim x}\right)\frac{1}{2x^2}$$

This equation will determine the attraction upon a point x, wherever it may be situated.

Required the equation to the system of lines in the trapezium ABCD.

(17). Let the origin of co-ordinates be at A. Put AE $= a$ and AF$= b$, AD$= c$



And let,

$y = e\,x$, be the equation to the line AB,

$y = a\,e$, do. do. BC,

$y = f\,(c - x)$, do. do. CD,

Hence,

$f(x) = e\,x$ ... between the limits $x = o$ and $x = a$
$f_1(x) = a\,e$ .... $x = a$ and $x = b$
$f_2(x) = f(c - x)$, ... $x = b$ and $x =$ indefinitely.

Substituting these values in formula for two breaks, we shall have—

$$Y_2 = \frac{A \cdot B}{4} \cdot ex + \frac{A_1 \cdot B}{4} \cdot ae + \frac{B_1}{2} \cdot f(c - x)$$

where, $A = 1 + \dfrac{a - x}{b \backsim x}$ and $A_1 = 1 - \dfrac{a - x}{a \backsim x}$,

$$B = 1 + \frac{b - x}{b \backsim x} \text{ and } B_1 = 1 - \frac{b - x}{a \backsim x},$$

Consequently, we shall obtain for the value of Y_2

$$\mathrm{Y}_2 = \left(1 + \frac{a - x}{a \backsim x}\right)\left(1 + \frac{b - x}{b \backsim x}\right)\frac{ex}{4} + \left(1 - \frac{a - x}{a \backsim x}\right)\left(1 + \frac{b - x}{b \backsim x}\right).\frac{ae}{4} + \left(1 - \frac{b - x}{b \backsim x}\right).\frac{\mathrm{f}}{2}(c - x)$$

$$= \frac{ex}{4} + \frac{a - x}{a \backsim x}.\frac{ex}{4} + \frac{b - x}{b \backsim x}.\frac{ex}{4} + \frac{(a - x)(b - x)}{(a \backsim x)(b \backsim x)}.\frac{ex}{4} + \frac{ae}{4} - \frac{a - x}{a \backsim x}.\frac{ae}{4} + \frac{b - x}{b \backsim x}.\frac{ae}{4}$$

$$- \frac{(a - x)(b - x)}{(a \backsim x)(b \backsim x)}.\frac{ae}{4} + \frac{2\,\mathrm{f}\,c}{4} - \frac{2\,\mathrm{f}\,c}{4}.\frac{b - x}{b \backsim x} - \frac{2\,\mathrm{f}\,x}{4} + \frac{b - x}{b \backsim x}.\frac{2\,\mathrm{f}\,x}{4}$$

$$= \left(e - 2\,\mathrm{f}\right)\frac{x}{4} + \frac{a - x}{4(a \backsim x)}.(x - a)\,e + \frac{b - x}{4(b \backsim x)}\left(ex + 2\,\mathrm{f}\,x - 2\,\mathrm{f}\,c + ae\right)$$

$$+ \frac{(a - x)(b - x)}{4(a \backsim x)(b \backsim x)}.(x - a)\,e + \frac{ae + 2\,\mathrm{f}\,c}{4} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

This equation will give the value of the ordinate parallel to the axis of y; and is much more convenient for use, I conceive, than the formula which is given by Mr. Kelland, in his Theory of Heat, pages 61, 62, 63, and 64; who, after three pages of long and elaborate investigation, ultimately arrives at the formula, which is as follows:

$$y = \frac{ce}{2\pi^2}\left\{\begin{array}{l}\dfrac{a'^2}{4} \\[2ex] +\,(a'\,\text{Sin.}\,a' - \text{vers.}\,a')\,\dfrac{\cos.\,z}{1^2} + (\text{Sin.}\,a' - a'\cos.\,a')\,\dfrac{\text{Sin.}\,z}{1^2} \\[2ex] +\,(2\,a'\,\text{Sin.}\,2\,a' - \text{vers.}\,2\,a')\,\dfrac{\cos.\,2\,z}{1^2} + (\text{Sin.}\,2\,a' - 2\,a'\cos.\,2\,a')\,\dfrac{\text{Sin.}\,2\,z}{2^2} \\[2ex] +\,(3\,a'\,\text{Sin.}\,3\,a' - \text{vers.}\,3\,a')\,\dfrac{\cos.\,3\,z}{1^2} + (\text{Sin.}\,3\,a' - 3\,a'\cos.\,3\,a')\,\dfrac{\text{Sin.}\,3\,z}{3^2} \\[2ex] +\qquad \&c. \qquad\qquad \&c. \qquad\qquad \&c.\end{array}\right.$$

$$+\frac{ca}{\pi}\left\{\begin{array}{l}\frac{1}{2}(\beta'-a') \\ +(\text{Sin.}\,\beta'-\text{Sin.}\,a')\frac{\cos.\,z}{1}+(\cos.\,a'-\cos.\,\beta')\frac{\text{Sin.}\,z}{1} \\ +(\text{Sin.}\,2\,\beta'-\text{Sin.}\,2\,a')\frac{\cos.\,2\,z}{2}+(\cos.\,2\,a'-\cos.\,2\,\beta')\frac{\text{Sin.}\,2\,z}{2} \\ +(\text{Sin.}\,3\,\beta'-\text{Sin.}\,3\,a')\frac{\cos.\,3\,z}{3}+(\cos.\,3\,a'-\cos.\,3\,\beta')\frac{\text{Sin.}\,3\,z}{3} \\ +\qquad \&c. \qquad \&c. \qquad \&c.\end{array}\right.$$

$$
+\frac{f\,c}{2\,\pi^2}\left\{
\begin{array}{l}
(2\,\pi - \beta')^2 \\[2ex]
-\left\{(2\,\pi - \beta')\,\text{Sin.}\,\beta' + \text{vers.}\,\beta'\right\}\dfrac{\cos.\,z}{1^2} + \left\{\text{Sin.}\,\beta' + (2\,\pi - \beta')\cos.\,\beta'\right\}\dfrac{\text{Sin.}\,z}{1^2} \\[2ex]
-\left\{2(2\,\pi - \beta')\,\text{Sin.}\,2\,\beta' + \text{vers}\,2\,\beta'\right\}\dfrac{\cos.\,2\,z}{2^2} + \left\{\text{Sin.}\,2\,\beta' + 2\,(2\,\pi - \beta')\cos.\,2\,\beta'\right\}\dfrac{\text{Sin.}\,2\,z}{2^2} \\[2ex]
-\left\{3(2\,\pi - \beta')\,\text{Sin.}\,3\,\beta' + \text{vers.}\,3\,\beta'\right\}\dfrac{\cos.\,3\,z}{3^2} + \left\{\text{Sin.}\,3\,\beta' + 3\,(2\,\pi - \beta')\cos.\,3\,\beta'\right\}\dfrac{\text{Sin.}\,3\,z}{3^3} \\[2ex]
- \qquad \&c. \qquad \&c. \qquad \&c.
\end{array}
\right.
$$

where, $\frac{2\,\pi\,x}{c} = z$ and $\frac{2\,\pi\,a}{c} = \alpha'$ and $\frac{2\,\pi\,b}{c} = \beta'$

Many more examples might be given, but we think that the above will be sufficient to illustrate the application of the general formulæ, which have been investigated in the former part of this paper. The methods proposed by Dr. Peacock, Dean of Ely; Fourier; M. Libri, and Murphy, to represent discontinuity, are given by Dr. Peacock in his well known and able Report, on the recent progress and present state of certain branches of analysis, made to the British Association for the advancement of science, Cambridge, 1833.

VI.—*On a new and practical Voltaic Battery of the highest powers, in which Potassium forms the positive element.* By JOHN GOODMAN, Esq.

(Read, October 20, 1846.)

POTASSIUM is well known in science as one of the most powerful chemical substances—possessing chemical affinities and powers of the highest order.

This substance appears to have been long known also in an electrical point of view, for we find it arranged by Sir H. Davy and others, at the head of a list of positive and negative metals in which it forms the principal oxidizable metal, being, with its amalgams, electro positive to all other metals arranged in electrical relations with it.

It was with this knowledge of the high powers of Potassium, that the author, whilst pursuing his researches into the analogy of Light, Heat, Electricity, &c. devised several experiments with the intention of constructing a voltaic arrangement, in which this metal should form *one element.* At first, the Potassium, amalgamated, was suspended by a copper wire in mineral naphtha, floating upon dilute sulphuric acid. In the acid liquid a plate of Platinum was arranged, in connexion with one extremity of the galvanometer, to the opposite extremity of which the Potassium wire was attached. On lowering the Potassium down to the surface of the acidulated water, a current of 60° or 70° was observed, and a strong action ensued, which after a few moments generally dislodged the metal from its connexions, and put an end to the experiment.

After many fruitless attempts permanently to fasten the metal upon its wire of communication, it was remembered that in one instance a very efficient voltaic pair had been formed, in which a simple copper wire of a spiral form merely surrounded the wet bladder in which the zinc element was immersed in dilute acid—being only

in contact with, and acting through the substance of the membrane although unimmersed in any fluid. Advantage was taken of this knowledge, and it was contemplated that Potassium might, as possessing such extraordinary affinities, also act upon water through an intervening membrane. Thus might its excessive action be moderated, and itself rendered probably quiet and manageable.

On the 5th of May last, the following plan was ultimately adopted after much consideration, and proved successful beyond my most sanguine expectations. A wine glass was filled with dilute sulphuric acid, and in this was immersed a plate of platinum just below the surface of the liquid. At the extremity of a short length of glass tubing, a piece of membrane was tied, so as to close up its lower end, which was by an appropriate stand so fixed, that the membrane, or diaphragm, should come in contact with the surface of the acidulated water, immediately above the immersed plate of platinum. Into this tube was dropped a globule of mercury, which, lying upon the membrane, would serve to amalgamate, and keep in that condition, the piece of Potassium destined for this situation. The tube was then filled with mineral naphtha, so that the metal

could be raised at pleasure into a medium in which it would remain perfectly quiescent, and would only suffer loss when required so to do.

The Potassium, weighing about half a grain, was now screwed upon the "tapped" extremity of the copper wire, upon which a shoulder, or button of wood, was also screwed, about one sixteenth of an inch from its extremity, to prevent the wire perforating the Potassium too far, and coming itself in contact with the diaphragm. This wire was (as is usual) in metallic communication with the immersed platinum, and for the purpose of raising, or depressing the Potassium in its cell, a moveable mercury cup formed the medium of communication. From this the Potassium hung suspended by its wire, upon which a small weight was affixed, to ensure the continuous contact and close application of this metal to the membrane.

With the apparatus thus arranged it was found that Potassium became a very *manageable element* in a voltaic battery; and on lowering it into contact with the diaphragm a continuous current of 45° to 50° was observed by the aid of an intervening galvanometer. To test the comparative

power of this arrangement with an ordinary pair, two plates—one of zinc, the other of copper, $2\frac{1}{4}$ inch by $1\frac{3}{4}$ inch—were employed in deflecting the same galvanometer. And it was found that in very fierce action in water, strongly acidulated with sulphuric acid, they only deflected the galvanometer to 65°, which in a few minutes fell to 61°, although at that period in fair brisk action.

Potassium Experiment—Aqueous Decomposition.

May 19th, 1846. Experiment 1.—Again arranged this Potassium battery as before, substituting however *solution of sulphate of copper acidulated with sulphuric acid* in the wine glass. The arrangement produced a remarkably quiet battery.

The deflexion of the galvanometer was but 10° to 30° when the decomposition apparatus was connected. Two platina wire poles, arranged as usual in acidulated distilled water, in a convenient glass tube for showing the development of the gas, formed the decomposition apparatus. The decomposition by *this single pair* was beautiful and *energetic ;* and what was remarkable, con-

tinued some time (decreasingly) after the platina plate was disconnected—the electric energy of the Potassium still inducing current.

Experiment 2.—With sulphate of copper solution, the next very small piece of Potassium gave only 10° of deflection, and 5° during decomposition, which was tolerably rapid. Afterwards, a deflection of 50° in another experiment, which fell to 5° in decomposition.

Experiment 3.—With *dilute acid* only, galvanometer 55°, but during *decomposition*, which was *very faint*, only 2½°.

Experiment 4.—*In neither case could decomposition be effected in a second decomposing cell.*

Experiment 5.—With a copper plate instead of platina, a deflection from 45° to 50° fell during decomposition, which was not powerful, to 5°. Decomposition could not be effected in two cells.

There is a peculiar property of electricity, exhibited in all its various modifications which is considered by the author as the *distinguishing quality* of electric force. It is first perceived in

the tendency of all substances exposed to the action of electric force, to assume what is termed *a polar condition.* It has been shown, by Dr. Faraday, to exist in the molecules of the various substances, which are interposed between the decomposing poles, or electrodes, of a voltaic arrangement.

The author suggests that it is this polar condition which causes, by the simple law of attraction and repulsion, the elements of any fluid, under decomposition, to progress towards, and ultimately to be deposited upon, or chemically combined with, that pole of the apparatus to which they severally belong, by a law as certain as the force of gravitation itself.*

This quality of electric force *does not depend upon the quantity of fluid existing in a circuit,* for the ordinary electricity manifests it in a much higher degree than does voltaic fluid, although

* As conduction destroys polarity, this polar condition could have no existence if the battery current were *conducted* by the electrolyte, as suggested by Dr. Faraday, and upon which basis the whole of his electric nomenclature is founded. (See Experiments 46, 48, and 49.)

the latter is found at all times incomparably greater in quantity. The author of this paper has frequently decomposed water in four successive cells, by the current from a single Electrical Machine, and yet, to effect decomposition in one cell by voltaic power, several pairs are required.

It is found that this state of polarization is at all times accompanied by other characteristics, in proportion to its intensity. It is observable, that the higher the polar condition, the greater are its powers of transmission, or conduction, through various known aëriform media, liquids, and solid bodies.

And when at its maximum, as seen in ordinary Electricity and Lightning, it is found to be accompanied by, and capable of inducing attraction and repulsion of whole substances of a light nature, as gold leaf, pith balls, &c. &c.

The power of *Chemical* combination and decomposition appears to be also dependant upon this quality, *or polar condition* of bodies.

Mr. Gassiot has shown, that deflection of gold leaf may be produced, or developed, by chemical

substances possessing the *lowest chemical powers* in voltaic arrangements, if a *sufficient number* of well insulated pairs only be employed; which he has also beautifully illustrated by a water battery of 3500 pairs.

So it is shown, by the following experiments, that a *chemical substance* of the *highest powers of affinity*, will develope, *by a very few pairs*, *the same phenomena.*

An attempt was now made to construct twelve pairs of plates of the description aforementioned. By means of glass pillars, and an appropriate frame work of wood, each pair was kept insulated from the other, and twelve wine glasses formed the jars for this beautiful little battery. The whole being completed, an attempt was made to produce the deflexion of gold leaf. A micrometer screw was arranged, so as to cause a copper disc to recede or approach the lower extremity of a suspended slip of gold leaf, and on connecting the poles of the battery with the same, a deflection was readily produced of above 1-10th of an inch, with twelve pairs. The solution of Sulphate of Copper was here employed *unacidulated.*

I believe Mr. Grove has succeeded in affecting gold leaves, by a small number of pairs of his gas battery; and I am not yet aware how small a number of my arrangement will produce sensible action upon the Electroscope, but shall shortly attempt this enquiry, when time permits.*

These experiments with Potassium tend to show, that there is a *very intimate relation* (if not a complete analogy) between electrical and chemical phenomena, as shown by Sir H. Davy. For the substance which possesses the *highest chemical affinity*, is here shown to manifest also the *most exalted electrical energy or tension, and vice versa;* and *this electrical energy is at all times proportional to the measure of the chemical forces employed.* The battery was, on one occasion, *kept in continuous action for two hours*, and, by a little contrivance, the Potassium was, in each cell, simultaneously raised from its membrane into the

* Since this paper was read, the author has attempted the deflection of gold leaf by six pairs, and succeeded very satisfactorily. Five pairs, four, three, and two were tried, and a measured deflection took place in each instance; and, ultimately, *one pair alone produced a sensible and measured deflection.*

supernatant naphtha, and remained there in a quiescent state until the following evening, when it was again used with facility: no loss having occurred, of any consequence, except in the giving way of three membranes.

It was found that, for delicate experiments with one pair, goldbeaters' skin, or turkey's craw is considerably more efficient than bladder: decomposition of water is scarcely perceptible when the latter is employed.

VII.—*Researches into the Identity of the Existencies or Forces—Light, Heat, Electricity, and Magnetism.* By John Goodman, Esq.

(Read November 3, 1846,)

On Thermo Electricity.

It was discovered some years ago by Mr. Sturgeon, that thermo Electricity does not require more than one metal for its development.

In confirming this discovery I have found that the current was developed only by the more *crystalline* metals, Bismuth, Antimony, Iron, Steel, Zinc, &c. as will appear on inspecting the accompanying Table.

I found also that each metal possessed its own distinctive and peculiar amount of current, as indicated by the galvanometer, and that, always

MECHANICAL ELECTRICITY.				THERMO ELECTRICITY.		VOLTAIC CONDITION, WITH ACIDS, ETC.
Metal, or Disc employed.	Tool, or Opposing Metal.	Current, and its direction, *as seen at the Galvanr.*	Simple Affinity.	Thermo electric Nature.	Currents and direction.	
BISMUTH DISC	Copper Wire	40° from the Copper towards the Bismuth	B. Electro-negative	B. Electro-negative	35° to 40° given out at its heated extremity to the Copper from its heated end	B. In Nitric acid with Platina or Copper, pos.
DITTO	Steel Tool	40° to 45° from the Tool	B. negative.	B. negative. in all	cases ditto.	
DITTO	Bismuth Rod	10° to 15° from the Rod	Disc neg…			
DITTO	Antimony Rod	45° from the Rod	B. negative.	B. negative.	$42\frac{1}{2}$° towards B.	
DITTO	Silver sharpened	40° from the Silver	B. negative.	B. negative.		
DITTO	Gold	35° from the Gold	B. negative.	B. negative.		
DITTO	Lead.	$27\frac{1}{2}$° from the Lead	B. negative.	B. negative.		
IRON DISC	Steel Tool	10° from the Iron	I. positive	I. positive	7° towards the heated end.	
LARGE DITTO	Steel Tool	20° from the Tool	I. negative	I. negative	*	
IRON ROD	Steel File	$7\frac{1}{2}$° from the Iron	I. positive	I. positive	7° as above.	
ZINC DISC	Copper Wire	3° from the Zinc	Z. positive	Z. positive	$2\frac{1}{2}$° to 3° from the cold extremity.	In acid sulph. dilute Zinc pos.
DITTO	Sharp edge of Copper	3° from the Zinc	Z. positive	Z. positive	ditto	As in Electro motion.
DITTO	Turning Tool	5° (by steam power) from the Tool	Z. negative.	Z. negative.	5° The Zinc current opposed that of the Iron	In sulphuric acid, Zinc pos. Iron neg.
DITTO	Iron sharpened	4° to 5° from the Iron	Z. negative.	Z. negative.		
DITTO	Bismuth Rod	12° from the Zinc	Z. positive			
COPPER DISC	Bismuth Rod	15° from the Copper	C. positive	C. positive	35° see above.	
DITTO	Rod of Zinc	$2\frac{1}{2}$° to 4° from the Zinc	Z. positive	Z. robs Cpr.	$2\frac{1}{2}$° as above	As in Electro motion.
DITTO	Sharp Iron	8° from the Iron	C. negative.	C. negative.	5° to $7\frac{1}{2}$° see above.	
DITTO	Steel Tool	$2\frac{1}{2}$° to 3° from the Steel	C. negative.	C. negative.		
DITTO	Copper Rod	0° simply a conductor	…	…	0° simply a conductor.	
BRASS DISC	Steel Tool	5° from the tool	…			
SILVER	Copper Disc	simply a conductor	S. positive	S. positive	1° to $1\frac{1}{2}$° towards the heated end.	
GOLD	Ditto	0° simply a conductor	…	G. positive.	$\frac{1}{2}$° to 1°	
LEAD	Ditto	from the lead	…	L. negative.	2° towards its cold extremity.	

* By *first* heating the Steel in conjunction with Iron, and giving it the greater influence of the flame, the current was reversed.—Iron neg. Steel pos.

in the same direction: that when two opposing metals were united in producing a thermo current, the minor current would be found to neutralize the opposing current, precisely to the amount of its own powers, and with as much exactitude as if it had been done by arithmetical calculation.

Thus iron alone gave $7\frac{1}{2}°$ current. Conjoined with Zinc 5°; Zinc alone $2\frac{1}{2}°$ in the opposite direction.

It was also discovered that a minor current conjoined to one of a more powerful nature, does not generally augment, but rather diminish the amount of the latter.*

I found that the uncrystalline metals, gold, silver, copper, lead, &c. were unable to develope currents of any appreciable amount, (as seen also in the Table,) although the heating process was continued to a considerable degree of intensity, (see 37, 38.)

* It was found that the crystalline metals, Bismuth and Antimony, which form the best combination for thermo-electric purposes, are naturally mutually reciprocal metals. Bismuth negative, 45°; Antimony positive, current $22\frac{1}{2}°$: and yet, conjoined, they only produced a current of 48°.

The experiments adduced show, that these latter metals may be simply regarded as conducting media to thermo Electricity, that they offer no specific resistance to the flow of current, and may, therefore, be employed either in conjunction with electro-positive, or electro-negative metals.

The results thus arrived at resemble much those evinced by the experiments of Dr. Franklin and others on the Tourmalin, in which ordinary Electricity was developed by heat alone, save that in this instance the electricity resembles the voltaic fluid, owing no doubt to the want of that complete insulation among the molecules of the metals, which is afforded by the Tourmalin.

It is remarkable that no polar fluid, or Electricity of any kind, is ever developed without the employment of a crystalline, insulating, or imperfectly conducting body. For in voltaic arrangements, *the Electrolyte is this non-conducting medium ;* in the cases just cited, the Tourmalin was the intermediate polar body; in ordinary Electricity, the glass cylinder is the non-conducting body, or "Electric," and in thermo, and mechanical Electricity, (hereafter to

be mentioned,) the crystalline metals, bismuth, iron, steel, antimony, zinc, &c. are found to be the intervening polar structures, giving rise to these forms of electric fluid.

The same remarks hold good also with regard to the polar condition and *insulating* properties, (witnessed by the author,) of high pressure steam in the generation of hydro-electric, and to the polarizable quality of steel and iron in Electro magnetic, magneto Electric, and magnetic phenomena.

In contemplating the known electrical phenomena which occur by the contact of dissimilar metals, and the processes of friction, pressure, fracture, vaporization, &c. and witnessing the effects which heat thus produces upon Bismuth, &c. I devised the friction of this metal in a lathe, as a preparatory experiment to some hereinafter contained, in hopes of being able to manifest *the continuous transmission of Electricity from the one surface to the other*, as evinced by a current passing through the galvanometer from or towards the other extremities of the metals employed. This, to my mind, would evince the *origin of radiant* heat, the *result of friction*, in the me-

chanical processes--drilling, turning, filing, &c.—and which, on its discovery, I named "*Mechanical Electricity.*"

In the printed report of the British Association for 1845, which met at Cambridge, I find that M. Paul Erman, of Berlin, presented a paper, containing one or two experiments of a somewhat similar nature to the Association, but of which I was not aware until the publication of the report, and the completion of many of my experiments.

April 2, 1846, I made the following experiment:

Upon a mandril of copper, a cylinder of Bismuth was cast. One end of the mandril was fixed in dry wood, and arranged in a turning lathe. The other revolved against the point of the "following up head stock," as is usual. The surface of the cylinder or disc was turned smooth, the mandril having been previously soldered to the Bismuth, so as to insure full metallic communication.

Instead of a metal rest, a wood one was now used, and afterwards a small piece of wood placed under the ordinary rest; to insulate this, and the

tool from the other portion of the lathe, was found to be *all that is necessary* in these experiments. A spring of brass wire was made to press firmly against the turning mandril, so as to ensure metallic contact; and its other extremity was in communication with the northern extremity of the galvanometer.*

In the following experiments, the direction of the current is simply stated, *as seen at the galvanometer*, which will be found, in all cases, to be the reverse of what takes place between the opposing metals. Thus, in the experiments in which *the zinc robs the copper*, as seen at the galvanometer, the current is progressing *towards the copper*.—(See 31, &c.) And yet the actual transfer at the surfaces is from the copper to the zinc.

Exp. 21. On applying the smooth surface of the end of a piece of *thick rod copper* to the turned surface of the cylinder, producing friction, a current was observed from the copper towards

* The Galvanometer, in these experiments, was not of the highest sensibility. It consisted of forty-six turns of copper wire, the $\frac{1}{25}$ of an inch in diameter. The needle was single, and had therefore a northern tendency to counteract.

the Bismuth. The rod copper was soldered to a wire in connexion with the southern extremity of the galvanometer.

Exp. 22. By accident the rod copper was torn away, and I applied merely the extremity of the connecting wire against the revolving cylinder. The galvanometer was deflected many degress, and considerably more *than by the friction with the larger surface. A large surface appeared to induce complex results, and to destroy elementary or simple indications.*

Exp. 23. By means of a set screw connected the galvanometer S wire to a turning tool, and slightly turning or shaving off ribbons of Bismuth, a considerable current was indicated *from the tool towards the Bismuth.* This experiment with the Bismuth disc and steel tool was afterwards repeated by steam power,—current 40 to 45° constant, vibrated to 80° or 90° at first.

Exp. 24. With a Bismuth rod against the Bismuth cylinder, a current of 4° and afterwards of 10° to 15° towards the cylinder was observed.*

* It is here seen that a preponderance is given in favour of the rod or tool, both metals being alike the rod is positive the disc negative.

Exp. 25. The Bismuth disc and an antimony rod gave a current of 45° in the usual direction for Bismuth—the antimony robbing the Bismuth. Antimony positive: Bismuth negative.

Exp. 26. Silver with Bismuth 40°. The usual Bismuth current.

Exp. 27. Gold with Bismuth 35°. The usual Bismuth current.

Exp. 28. Lead with Bismuth 27½°. The usual Bismuth current from the lead to the Bismuth.

Exp. 29. *With an iron disc*, rotating under similar conditions, I obtained, by a turning tool of steel, *a current of* 10°, *from the iron towards the tool.*

I tested the galvanometer by a voltaic pair, to see the direction of the current, and found the direction as stated to correspond.

I repeated afterwards the same experiment, by steam power, with a much larger cylinder of cast iron, apparently harder than before, and the needle vibrated from 15° to 30°, stationary at

20°; the current, in that instance, *from the tool towards the disc*, tested by voltaic pair.

Exp. 30. *With a zinc disc* and steel tool, at first no certain indication of current. Repeated afterwards, with and without steam power, current 3°, and afterwards 5°, constant, from the tool towards the zinc.

Exp. 31. With the extremity of the copper connecting wire, current $2\frac{1}{2}$° from the zinc towards the wire. Repeated with steam power, 3° towards the copper.

May 1st, 1846. With a sharp cutting edge of copper against the zinc disc, 3° to 5° towards the copper. These experiments *correspond with the phenomena of electro-motion*—zinc robbing copper.

Exp. 32. With a Bismuth rod against the zinc cylinder, a current of 12° was evinced from the zinc towards the Bismuth.

Exp. 33. With a piece of iron sharpened, current 4° to 5° from the iron towards the zinc, iron positive, zinc negative.

Exp. 34. May 2. *A copper disc* rubbed by a rod of Bismuth, current produced vibrating to 30° stationary at 15° *towards the Bismuth from the copper.*

Exp. 35. *A rod of zinc* against the same copper the edges of the disc being made sharp, 2½° towards the copper, with a good cutting edge, 4° constant. The zinc by this means being well cut. Repeated 4°. Zinc robbing copper as in Exp. 31.

Exp. 36. A piece of iron made sharp with filing, when used with a large copper disc, 3½ inches in diameter, gave a current of 8° stationary, while the edge remained good and removed shavings, from the iron towards the copper, iron positive.

Exp. 37. Employed a piece of rod *copper*, in friction against the revolving *copper* disc, and not the least indication of current was observed.

Exp. 38. Silver thus employed against the copper dise, gave a slight current of 1° from the silver towards the disc.

Exp. 39. With a steel tool, a constant current of 2½° *towards the copper.*

Exp. 40. A brass rod turning instead of a disc, and steel tool, current 5° from the tool towards the brass.

Magnetism.

Exp. 41. By filing iron with a steel file, a current of $7\frac{1}{2}°$ is produced, from the iron towards the file, and the two metallic bodies become oppositely magnetic, as shown by the following experiments.

The steel surface becomes positive, and the iron negative, which are electro polar conditions.

It will be immediately seen, that not only does the friction of a file upon a piece of soft iron induce two oppositely electrical conditions of surface, but that this *electrical state is also a truly magnetic condition*, and offers an explanation how, or *in what manner the various mechanical operations, screw tapping, drilling, filing, &c. evince magnetic phenomena.* An attempt to establish the opinion of magnetism being a *static electro polar condition*, was by the author of this paper brought forward, and published in the Report of the British Association, for 1842, page 17.

Exp. Having selected a steel file and piece of fine iron wire, free from magnetic polarity, I proceeded to draw the file several times over the surface of the wire, when by holding them on each side the north-pole of a suspended magnetic needle, it was found that the wire attracted, and the file repelled this pole with considerable force.

Exp. A new file attracted both poles of a magnetic needle, or was unmagnetic. A piece of iron wire slightly *repelled* the pole. After rubbing the wire along its surface, and holding the wire on one side of the north-pole, and the file on other, the needle was *attracted by the wire, and repelled by the file.*

Exp. A new file attracted the north-pole of a magnetic needle 10°, a piece of iron wire repelled the same. After filing the same, and placing this pole of the needle between them, the file repelled, and the wire attracted the needle. This experiment was repeated with the same result.

A thick file, and a thick piece of soft iron did not produce any change, the process not

being sufficiently powerful to induce magnetic polarity in any considerable mass of metal.*

Exp. Another file was neutral, rather attractive. The repulsive end of a piece of magnetic iron wire was employed. After filing briskly around the surface of its extremity, *the file repelled*, and the *wire attracted* the north-pole.

Exp. Took the opposite extremities of the file and wire, the wire repelled, the file attracted, but on rubbing them together, an instant change took place. *The file repelled, and the wire attracted the needle.*

Repeated with the same results. These operations were performed when the metals pointed southward. It was discovered, however, that an opposite result took place when the filing was performed towards the north. The file then attracted and the wire repelled the north-pole; but the evinced trifling difference of affinity between iron and steel, as shown in (15) may tend

* The finer the materials employed the more highly developed were the magnetic effects, and on this account iron *wire* was used.

to produce this uncertainty, which subjects them to the government of the earth's polarity.

Is the current induced by mechanical operations, simply thermo Electric or not?

Exp. 42. Immersed the lower half of the Bismuth cylinder in water at 55°. By turning it with a steel tool about one minute, (the water revolving around the cylinder the whole period,) a current was constantly maintained, at length from 35° to 40°, fine turnings being produced.

The water, 9 oz. and 2 drs. in which the Bismuth disc was immersed, and which would derive the principal part of the heat from the whole process, being heated only to 57° or 2°,* and the tool immersed in a like quantity of water, was found to increase it only half a degree.

Exp. 43. A conducting wire, made to press against the revolving Bismuth disc slightly,

* Observe, the *turnings alone* which were made, would, as will be hereafter shown, heat the water nearly to this amount, and the *tool* would in this instance heat the water more than the disc. Therefore the heat derived from the disc would be less than ½°.

produced a current of $2\frac{1}{2}°$ to $5°$. But on using a disconnected turning tool to the same side, and near the wire, the current was still $2\frac{1}{2}°$ to $5°$; and yet the tool could have induced a current of $30°$ or $40°$. On increasing the pressure of the wire against the cylinder, current $6°$ to $9°$. On using the turning tool as before, no increase of current could be perceived. Yet, on applying a lighted taper at the junction of the wire to the cylinder, current $35°$.

The turning tool does not, therefore, *augment the heat of surface of the disc*, so as by heat to produce a current of thermo-electricity.

Exp. 44. Attached the two galvanometer wires to the piece of Bismuth used in the experiments for the production of thermo electricity, one at each end. Rubbed *one extremity of the Bismuth* with force against the revolving copper disc, for one minute, and yet *no current* was indicated, which would have been the case, if the heat developed by friction in these cases had been the source of development of the fluid. For instantly on applying the *same end to the flame of a spirit lamp*, the galvanometer began to deflect. Repeated the experiment with like results. And on

removing the wire at the end of the Bismuth, next to the copper disc, and attaching it to the spring which connected the mandril with the galvanometer, for mechanical Electricity, a current *was instantly produced by the same friction.* Repeated, and with like results.*

Exp. 45. Repeated a similar experiment with iron. The sharp iron of exp. 36, was attached to the two galvanometer wires, one at each end. On turning with its sharp extremity, the copper disc for some time, which produced an instantaneous current in exp. 36, no deviation of the needle was at all observed. But by holding the same end of the iron for a few moments in the spirit flame, a constant deviation commenced, which gradually progressed to $7\frac{1}{2}°$.

Repeated the experiment with like results. Yet, when the end adjoining the disc was disconnected, and attached to the spring in contact with the mandril, i. e. *the ordinary connexion for mechanical Electricity*, being made (as in 36) *an instantaneous current of* 8° (*stationary*)

* The metals here employed are the crystalline, which have been shown to be the only bodies evolving the phenomena, copper being only a simple conducting body.

was the result. Thus it is seen, that with the *same heat developed* in each case, by the mechanical arrangement, is given an immediate current, which heat will not give current at all by the thermo Electric process, and it is therefore evident *that thermo and mechanical Electricity are not derived from the same source.*

These experiments appear very decisive. The fact of the current invariably *pursuing the course of that in electro motion, or contact of dissimilar metals*, in all cases where metals illustrative of this phenomenon are employed, speaks in favour of the dissimilarity of the source of these two modifications.

It is also to be remarked here, that if mechanical Electricity were the result of the heat applied to the extremity of the metal, *the friction of flat surfaces, which is known to produce much more heat than simply cutting or turning with a sharp edge*, would produce the greatest deflection of the needle; but by this means it is found, that none, or scarcely any current is developed, even with a disc of Bismuth. (See 22, 23.)

Exp. 46. Is mechanical or thermo Electricity

conductible by water? A rod of Bismuth was arranged for thermo Electricity in this experiment, and the voltaic decomposition apparatus was employed, and it was discovered that the thermo Electric current is utterly *inconductible by water or acidulated* water; the heat was carried on to fusion, but the galvanometer did not deflect in any appreciable manner. It is also inconductible by a strong solution of sulphate of copper.

Exp. 47. The thermo Electric current from Bismuth passed through a *large piece of Bismuth* deflecting the galvanometer gradually up to 15°, by the steady heat of a spirit lamp.

Exp. 48. Mechanical Electricity is not conducted at all by *solution of sulphate of copper.*

Exp. 49 And is also *inconductible by acidulated water*, in the ordinary decomposition apparatus.

Exp. 50. But is readily transmitted by an intervening *piece of Bismuth*, of equal temperature.

Remarks.

The *direction* of the current from every individual metal, and from one metal relatively with another, is at all times *invariable*, both in mechanical and thermo Electricity.

The *quantity of force* circulating through the galvanometer, and proceeding from any given metal or specific pair of metals, is constantly about the same in amount, proportional to the intensity of the developing process, in both modifications. Each metal *evinces an amount* of force *comparatively proportional* with that of every other metal employed, both in the mechanical and in the thermo Electricity.

VIII.—*On the Maturation of Grain and Farming Produce, so as to be most beneficial to the Cultivator.* By John Just, Esq.

Read August 10th, 1847.

Every building is designed for some use; has some special purpose to serve in human economy. Just so, every vegetable production has certain ends to answer in the economy of nature, for which its whole structure was designedly reared, and the plant itself primarily intended. One main end of a plant's existence is fructification—or the bearing of fruit, and the maturation of the seed. And, since fruits and seeds, with such parts and organs of plants as serve to prepare material for them both, constitute a considerable portion of the food of man, and the whole food of such animals as man has taken under his care for domestication, and sundry services, a knowledge of the formation and physiology of the fructifying organs, functions, and requirements of plants, may be considered as the ultimatum of

all cultivation; inasmuch, as such knowledge alone can enable man to guide the growth of plants, govern and control them, towards that perfection, which can secure to him the full benefit of all his toil, and culture.

Animals must have attained, or nearly so, their full growth, before they are fitted for the reproduction of their species. Changes take place in their system, prior to this cessation of growth, as preparatory to the due discharge of their reproductive functions. So likewise in plants. They either cease to grow, when fructification ensues; or the parts, designed for fructification, have attained such vigour, and undergone such changes, as enable them to perfect the same. To understand, then, the laws by which the principle of fructification operates; and to know those conditions, which modify such operations until maturation is fully consummated, is as much the business of agriculture—(and much more conducive to its profitable returns) as skilfully tilling the ground, or properly performing the requisite manual labour.

The different kinds of grain supplying mankind with bread, which has been so aptly termed the

"staff of life," stand first in importance to the cultivator. Wherever civilization has extended, an adequate supply of grain has been considered as essential to the well-being of the community. The want of such a supply we have all felt, and partly still feel, and we need not apply to the annals of history for vouchers to such an assertion. Whatever, then, tends to promote the growth of grain, and multiply its increase—so as to make bread plentiful, and good, and cheap, is worthy the attention, not merely of the cultivator —but of every one, who feels interested in the weal of his fellow-men ; and rejoices, in the common good of his country.

The vegetable structure has been reared in all kinds of grain, before fructification commences. Every culm or straw has shot up aloft into ear, and the air, so as to command the full action of sunshine and daylight. The organs also have been changed by the accession of a new principle, and along with this change, not merely the organs themselves, but a change of functions has also been introduced throughout the whole plant. The roots extend themselves no farther within the soil. The blades have attained their full size and proportions. And within the culm has ac-

cumulated much saccharine matter, which existed there not previously during its growth. The activity of vegetation has yielded up its energy to invigorate the fructification now to take place. And as all growth has ceased in the vegetating organs, we may infer, that the wants of the grain, from the period when fertilisation fecundates the ovules, until full maturity succeeds, must be mainly supplied from material already within the fabrick of the plant, either stored up in its tissues, or diffused throughout its juices, that it may be ultimately carried up into the grain, and expended in its formation and completion.

If we are curious enough, and sufficiently patient to follow thoroughly the processes which are now going on in the plants, we shall be enabled to see the reasons of the just mentioned change. We shall perceive that the store of saccharine fluid is directed upwards into the floral integuments, and that they, excited by its influence, open and liberate the fructifying organs; and that these again excited by light, and surcharged with sugar, fecundate the ovules. And so essentially necessary is this saccharine matter, and so fearful is nature of a failure for want of a sufficiency, that not merely is the free sugar

accumulated within and around them, but every isomeric substance therein converted into sugar, and concentrated there, that there may be a superabundance. Throughout all Flora's domains, wherever her marriage rites are being consummated, she makes a feast of nectar for the guests which she invites to be present on the festive occasion. There is always joy on the earth whenever a germ is laid for a future existence, whether one being more is about to be added to the great household of God, or provision merely made thereby for its maintenance and enjoyment. There is no parsimony of good things in creation. Hence honey from the flowers of the fields for insects and bees, and from the bees for man; hence wines made from various kinds of flowers for the home use of frugal ladies; and hence hundreds of other little facts all unknown to uninitiated minds.

A striking analogy thus manifests itself between the fecundation of the ovules of grain and seeds and their germination. Sugar must be present during both processes; and every substance that can furnish sugar, either by a transmutation of the arrangement of the elements themselves, or by throwing off any excess of carbon, readily

does so. The very foundation of the future grain is laid under exactly parallel circumstances, and under similar conditions to those required for the developement of the future plant it contains; so that if sugar be wanted, as among the grasses, it must be secured during the epoch of their flowering, just as it is during the epoch of germination in the malting of grain.

When the ovules of each grain have been thus fecundated, and the germ of independent vitality introduced into them, then fructification, properly so called, commences. The sugar in excess is absorbed, and gradually commuted into other matter, such as forms the nucleus of the seed. Carbon again is appropriated, and the ovules swell out into grain by drawing upon the stock of provisions within the blades and culms. And, as no carbon can be appropriated but under the direct influence of sunshine and daylight, the direct action of light and of air is essential to the thorough fructification of the grain. Whatever precludes the one or the other of the two, checks fructification, and maturation never succeeds. It is owing to this interference with both light and air, that grain cannot properly ripen under trees and tall fences Trees belong to woods and

lawns, parks, pleasure grounds, and forests—and not to arable fields; and tall fences, with their fine-spreading trees, though charming and picturesque in landscape, are fitter for employing the pens and pencils of poets and painters, and attracting the eyes of travellers and tourists, than for profiting the population of the country. Want of light, and of a free circulation of air, is likewise the reason why crops of grain, when lodged by falls of rain, and a too rank vegetation, are always inferior in quality of produce; because fructification has been checked, and maturation never completed.

Two special objects are provided for by the natural maturation of grain and seeds; the one is an adequate supply of material to serve as food for the embryonic germ to draw upon when it developes itself; and the other, furnishing to the grain and seed such protection against the influence of conditions under which they may be placed, as will prevent them from perishing, or being unseasonably called into vital action. And herein the purposes of nature and the advantages of mankind are quite different. Man wants grain only to supply him with a suitable portion of the aliment which nature has stored up within it for

far different purposes. What he appropriates is what the grain yields but sparingly, and wants not for food, but for vital stimulants. Yet so easily given up is such matter to man's digestive organs, that it becomes the most nutritive and wholesome kind of food for him—the quantity required for his sustenance eking out for the poorness of the quality. And, as it is well known that the azotised parts are those which he particularly requires, the question is—how to know when such parts are most abundant.

If we test carefully the seeds of grain at intervals, from the period of fecundation till full maturation, we shall find that, as the grain gradually swells, the azotised portions, at first indeterminately small, slowly increase, until the grain has acquired its maximum size, which is about a fortnight before thorough maturation. Thenceforward ripening consists in the consolidation and enduration of the external and internal parts, as a protection against contingencies. During the first period of time, a supply of provisions is gathered round the germ for it to draw upon in due season. During the second period, provision is made for the conservation of the germ and seed until that season. The first

period is employed in drawing together the whole stock of material in the plant, and concentrating it within the grain. The second, in disposing of it, so that it may be kept uninjured and unimpaired, until it may be wanted. The one is the season of fructification, or the building up of the grain ; the other, of protecting and furnishing and maturing it for ulterior ends and purposes. Fructification brings the albuminous portions of grain to their maximum. Maturation preserves the whole, by introducing the most indestructible of all elements, carbon, in excess into it. And this is done by slightly diminishing the azotised combinations, as tending to induce a contrary result. So that thorough ripening of grain chiefly hardens and endurates the testa or husk, which we reject as unfit for food, at the expense of the material which alone can nourish us, it betters the bran, &c. but impoverishes the flour and the meal.

As nature intends the seeds of grain to germinate soon after they are shed, this diminution of the useful parts of the grain is exceedingly slight. Still there are other considerations which make this a subject of much importance both to the farmer in particular, and the population of a

country in general. Whenever grain is allowed to get fully ripe, it becomes exceedingly liable to shed itself in both reaping and gathering, which is not the case when less so. And when the cultivator knows that he thereby gains no advantage, but even sustains, a little loss in the quality of his grain, by allowing full maturation to overtake it, then his own profit will lead him to reap earlier, in order to secure a greater and better return therein. And even this is a trivial advantage—compared with that of housing his grain in good condition ; (which an early harvest almost invariably secures to him in our fickle climate), especially in late seasons, when a fortnight is of more consequence to the welfare of the nation—than to be thrown away by the ignorance of custom—or the follies of farmers' fancies. Whenever, then, fructification ends and maturation begins—grain ought to be reaped, be the season what it may. For though the per centage gained in quality thereby, may be apparently very small—the saving of quantity throughout the kingdom of what is uselessly shed on the ground, averages year by year, not much less than the quantity of the seed sown.

What is true of wheat, oats, &c. is true also of

barley. But as most of this kind of grain in this country is employed for malting; and as fully ripening makes less difference in the farinaceous than in the azotised portions, the consequence is of no moment. Indeed, according to the present state of the excise laws, malsters are almost compelled to use fully ripened grain; otherwise they run great risk of over malting; since they are bound to their very time in making their malt. The riper the grain, the slower germination is in commencing, and the more tardy in going on. A fact not to be overlooked at present, because it shows us, that grain gathered when most profitable for food, is also best for sowing; in that it germinates sooner, and pushes on more vigorously. Such advantages may be but scarcely apparent; yet, in the aggregate they are mighty in their results. All maximums are made up from the summation of almost imperceptible minims. And were it not so, a knowledge of such matters is of vast moment; because it enables the farmer to know what he is about; to assign reasons, to calculate ends, and to lay down his plans judiciously, as every man ought to do, who is master of his business; and expects such success as he deserves, to follow as the result of his labours.

Next to crops of grain, as an article of food, stands the crop of potatoes. And as they have to store up and mature within their tubers, a similar kind of matter for similar purposes, it may be useful to enquire into their economy, that we may thereby ascertain the proper time for gathering them, to secure to ourselves their full value. The tubers of potatoes, physiologically speaking, are not of the nature of roots, as generally supposed, but subterraneous stems. Like stems, they therefore, bear buds, and contain proper stores of material for the developement of these buds; but being only annual in their duration, their tissues are chiefly cellular, that they may contain such stores. In their structure they are hence more analogous to seeds, and the stores of material they contain in a great measure similar. They, hence, undergo like seeds, maturation, in order to make similar provisions, and be similarly protected. What changes they undergo, and what these provisions are, we will now endeavour to ascertain.

Potatoe plants have two seasons of growth before maturation commences. During the first, they develope their ryse or haulms, as axes of vegetative growth. After this full expansion of

the vegetating organs, the vital energy of the plants is no longer expended in framing the structure of the same, but the elaborated juices are sent down from the leaves through the haulms, to form the true stems or tubers within the soil. This is their second period of growth. This continues until the tubers acquire their full size, and compliment of constituent parts; and varies in time according to the variety of the potatoe plant cultivated. Generally by the end of September, or the middle of October, the sorts cultivated for winter consumption have completed their growth. Maturation now begins, and such changes are effected within the tubers, as within seeds, as fit them for their season of repose. These consist in converting the fecula into granules of starch, and so endurating each granule as to enable it to resist the action of the fluid matter, in which it is embedded, by becoming insoluble; and in concentrating around the eyes or buds the azotised matter, that it there may be in readiness to form the diastase, which has to awaken the vitality of the bud; and like chyme in the animal system, dissolve and convert into sugar the amylaceous portions, for the purposes of the germination of buds in the following season.

From these physiological facts, we may learn, that as articles of food, potatoes, like grain, are fit for gathering when they have acquired their full size, and when maturation is going on ; and that the changes which take place during maturation, are merely such as accommodate them to season and the circumstances which surround them. Farmers have hence a choice of time that they may make subservient to their convenience, and to the state of the weather; which they cannot have with respect to crops of grain. The only care which they require, is in storing them up for future use, and not being induced to gather them before they are fully grown, for fear of wasting their produce.

By attending closely to nature, and testing at intervals the condition of the tubers of potatoes during the winter months, we shall find that no change takes place in their constituents as articles of food, until the end of March, or the beginning of April. The buds then begin to sprit, and from that moment the potatoes deteriorate in value. The great object in storing them, is to prevent them from spritting prematurely. And this may be done, either by keeping the tubers thoroughly dry in a dark place, and in thin strata,

during the winter months, out of the reach of the frost; or, by covering them in thin strata, with sand or soil, in root houses. And, if such convenience be not at hand, they may be put down about five to ten inches in thickness, in an orchard or garden, or corner of a field, or some such similar places, and covered about a foot deep with soil, so as no frost can reach them; or perhaps, better still left in the drills, and covered over with soil, by running a plough between the drills, as turnips are left and preserved during winter, in the southern parts of France.

We must not allow the physiological facts just mentioned to pass over without drawing from them certain deductions of much practical importance. The first is, that the aliment which most benefits us, is more concentrated beneath the buds, and near the skins of the tubers, than elsewhere. Peeling potatoes before they are cooked, hence robs us of the best part of their substance. No wonder that pigs, poultry, and cattle thrive so well upon the peelings of potatoes, when in the wantonness of our ignorance we supply them so plentifully, as hitherto has been done, with thick parings. If we mean to

economise, we must boil them in their "jackets" as the Irish do; and though late, we must learn that we require the aid of science as well to cook potatoes as to grow them, and keep them properly. Another deduction is, that the quality of potatoes is better at the crown end. This is very evident in certain varieties of the Kidney sorts, where the eyes or buds are clustered thick there, and are wholly wanting at the other, or pendulum end. When cooked, the pendulum ends of such potatoes are very mealy, and the crown ends waxy in their texture, owing to this difference in their component parts. Mealy potatoes may be most relished, but unless the best parts are carefully kept with them, they are far from being the most nutritious. From the azotised parts only we derive flesh and fibre for the support of our frames, and though we retain for other purposes in our vital economy, modicums of the rest; we nevertheless eject the main mass, as useless, out of our systems.

Potatoes have been subject, particularly for the last two seasons, to blight and disease, which have rendered them unproductive to the cultivator, and scarce articles of food to the consumer. In consequence, a cry went forth that the species was

worn out, and was becoming extinct, from long cultivation. When did a plant wear out with cultivation? Varieties may fail because nature has not provided means for their renovation; but not so the species. Civilisation may as soon extinguish man, as cultivation destroy the plant it intends to cherish. Both may and will exhaust what has become weak and effete, but they more than compensate for the loss in the vigour and variety they supply. There never existed a bane without an antidote; just as there never was action without a counter action—never force in exercise without its antagonist. And, as surely as there is a check for smut and ergot in our grain crops, so surely is there one for the blight and the murrain among potatoes—when the causes of the diseases have been truly discovered, and the conditions which favour their spread most ascertained.

As there are strong reasons for considering the maladies just mentioned to be owing to a want of due maturation, it may not be a digression, too wide from our subject, briefly to examine them physiologically at present. The blight which was so rife during the last summer manifests itself first in the fluid contained within the cellular tissue of the two disks of the leaves, or in what

botanists term the dienchyma of the leaves. It is at first a mere discoloration; and never shows itself until the axis of growth and the leaves have acquired their full expansion. It appears, hence, a diseased state of the juices of the leaves. This speck of discoloured fluid spreads within the cellules, until it reaches the nearest stomata or breathing pores, on the under disk of the leaf. Immediately after reaching the pores, the mycelium of the Botrytis Solani of Hartig (the B— infestans of Berkley and others) shows itself on the under disk. And as a Botrytis can only germinate in morbid alkaline matter, its presence indicates that the discoloured fluid is of an alkaline nature. A black blotch now becomes visible externally, and spreads itself rapidly along the substance of the leaf. The cellules themselves are dissolved by the gangrenous fluid, and in a few days the whole leaf falls in a deliquescent mass. If it falls upon the haulm in this state, the virulent matter blisters the epidermis of the haulm; but as, at this period of the haulm's growth, it contains no stomata or breathing pores—no fungus appears; and the fibrous tissues beneath the epidermis, not being soluble in the virulent fluid, the mortification is not communicated to the haulm—but being bereft of its leaves, and its natural supplies

thence cut off, the haulms dry up, and wither away prematurely. The same is the case with tubers. Being deprived of their due supplies of generative sap, they neither attain their full growth, nor contain full equivalents for thorough maturation.

It hence appears, that the virus commences with the Botrytis, and is the result of its action and deliquescence; and not the predisposing cause of its existence. For the diseased fluid seems not to dissolve the cellular tissue previous to the appearance of the fungus, nor does the fungus spring from the virulent fluid on the blistered haulm afterwards. And dryness, stops the progress of the blight, by withdrawing the condition necessary for the spread of the fungus. I have leaves of potatoe plants in almost every stage of the disease, when the blight was arrested by the dry weather, which commenced on the 25th of August of last year. A crop of potatoes was saved almost entirely by this change in the weather, on a farm adjoining my cottage. Dry air promotes the transpiration and aëration of the juices within the leaves of plants, and stays the growth of all fungi. Hence, dry weather is a check to the blight in all its stages.

From the fact, that the virus of the blight is not absorbed by the haulm or stem of potatoe plants, and, therefore, not transmitted thence to the tubers within the soil; the murrain which attacks the tubers, cannot be occasioned or in anywise induced by the blight. The murrain of 1845, in this neighbourhood, began after the frosts of the 23rd and 24th of September of that year, without any previous blight on the leaves of the plants. As this frost cut down the haulms before the entire growth and full maturation of the tubers, the juices within, next to the cuticle and epidermis where most azotised, were left in an immature and thence unhealthy state, and therein originated the predisposition to the disease. This was the reason, that at the time of gathering the crops, little was seen of the murrain. It was only after having been a short time in the stores, that this disease showed itself, so as to become alarming. And as it spread most rapidly throughout the stores, commencing frequently at the unsloughed pendulum ends of the tubers, the notion arose, that as first appearing there, the disease had been communicated from the stems. Such potatoes, however, as had eschars formed by the natural sloughings of the pendulums or strings, withstood the infection, and

by timely separating them from the mass, a considerable portion of the crops of 1845 was saved for the consumption of the community.

The murrain first shows itself, like the blight, in the fluids of the cellules, just beneath the skins of the tubers. No fungus shows itself externally, until the disease bursts through the cuticle and epidermis. Nor does the disease spread freely until the appearance of the fungus. By keeping the tubers dry, and preventing fungi from germinating at all, the tubers may be kept from two to three months, before they become unfit for food. By placing the tubers dry in a window, I have been able to watch the progress of the disease daily, from the first speck discernible by a powerful microscrope; until the disease has wholly penetrated the substances, or has been entirely stayed. And my winter's stock of potatoes, for the last two years, by being kept thoroughly dry, has not had a score of defaulters, that were deserving of being outcasts, although specks of the disease have been found upon many among the rest.

From the immature state of the tubers, the azotised parts next to the skin, seem to be in an

unhealthy condition; and like all organised matter, wherein azote exists as a constituent, has a strong tendency to run into decomposition, when not checked by an excess of carbon. The alkaline portions free themselves from their combinations, and form ammonia. Hence the fœtid smell of decayed diseased tubers. This first deranges the cellules next to the skin, and during this period the progress of the disease is slow. But the brown fluid by degrees dissolves the cellules, and by leaving the granules of starch intact, cavities are formed thereby in the substance of the tuber, wherein soon develope themselves various kinds of fungi, as the Polyactis alba, Spicaria Solani, Fusisporium Solani, F— didymum F— candidum, &c. These fungi seem to spring from the amorphous mass of dissolved cellules, as therein we first observe the filaments of their several mycelia; and increasing speedily within, at length rupture the epidermis, and then assume their several generic and specific characters. The murrain now spreads rapidly, and penetrates the internal parts, making cavities in its progress, wherein the fungi form and mature themselves; and the granules of starch before intact are now infected, and assume the brown tint of the murrain, have their external lamina dissolved thereby,

until the tuber is thoroughly converted into a brown morbid mass.

From numerous failures during the winters of 1845 and 1846, in attempts to infect sound tubers with the sporules of the fungi it seems that the disease cannot be communicated by them. In all cases observed, the disease has commenced before they make their appearance. And as it is the special office of all these parasites, by preying upon diseased and dead vegetable structures and organs, to remove what has become useless for vital and healthy purposes, and inert, because defunct, in order that their elements may enter speedily into more active and vigorous combinations, these fungi cannot for this reason be considered as the cause, but the consequence of the disease. I have seen tubers wholly infected without the slightest vestige of a fungus; yet, far as I recollect, such tubers were infected by others, and not those which had the disease engendered within themselves.

During the last winter, I have repeatedly inocculated ripe sound tubers with the virulent matter of the murrain, and thereby induced the disease. This may account for the spread of the

disease in the stores of 1845, by communication through the unsloughed part of the pendulum, or string attachments, from want of thorough ripening. The same fact may also account for the spreading of the disease through cuts, wounds, and the burrowing holes made in some potatoes by worms and insects.

I have never seen the attack of an insect followed by gangrene or murrain. The gangrene may infect a leaf attacked by aphides, but as it infects others indiscriminately, that attack can by no means be regarded as its cause. At present there may be seen in all our potatoe crops, leaves infested with the Aphis vastator of Smee, where there is no blight, and contrariwise, blight where there is no Aphis. It stands as a notion, without the support of a single parallel throughout the whole domain of the vegetable creation, that a parasite should poison the food intended to nourish it. Parasites may stunt the growth of plants, malform their organs, by vitiating their juices, or abstract the whole of the nutritive fluid intended to support them, and so cause them to perish, as may be seen in the bean crops, &c. at this moment.

The soil seems in some way to be connected with the diseases. Certain varieties of the potatoe in a great measure escaped both the blight and murrain, last summer, on the high grounds behind my cottage, which were thoroughly infected with both in the Fylde country. And at present the blight and incipient murrain may be seen in gardens and grounds where potatoes have been for some time cultivated, while in the same district little of either is to be seen in the open grounds where potatoes are seldom planted, or come in only in rotation. And as far as my observations have extended, the best potatoe districts, where the plant has been longest and most successfully cultivated hitherto, have suffered the most so far.

Atmospheric influences have likewise been alleged as the cause of failures and disease. These undoubtedly have their effect, especially in the production of fungi. Perchance also the vitiation of the juices may be due in some degree to the unusual quantity of vapour with which the air has been charged during the last two summers. Psychometric observations give a great excess of the presence and pressure of vapour for the months of July, August, and September during 1845 and 1846. Yet, as in the same field differ-

ent varieties of the potatoe plant have been differently affected by the maladies, we cannot conclude atmospheric miasma to be the prime cause of these maladies. The state of the air may, notwithstanding, partly account for the higher grounds suffering less from the diseases than the low grounds; because there transpiration and aëration could be more fully carried on, and the generative sap in consequence become more carbonised, and thence better fitted for withstanding the disease, and discharging vigorously the vital and healthy functions of the plants.

The diseases are not congenital. I have grown sound tubers from infected ones. At present I have six plants growing, the offspring of six infected tubers, kept throughout the last winter in a window, to prevent them from complete infection, which are without speck of blight or indication of murrain, though more than one half of the tubers when planted were wholly disorganized. Vigour of growth too is a great check to the spread of the diseases. I had, last summer, sixteen plants left in the soil during the winter, *on the same plot of ground with the spring planted potatoes*, which had only a very few leaves blighted, and but four potatoes diseased,

while the spring planted ones of the same kind had scarcely a leaf which escaped, or one in six sound tubers.

It appears then, that the diseases are as much owing to a want of natural maturation of the tubers and haulms, as to any other cause discovered at present. They may be diseases of cultivation, brought on like diseases of civilization and domestication, by an excess of stimulants, and a preponderance of decomposible substances, not fully matured, nor thrown out of the plants, by natural processes, when under unfavourable conditions. If so, they must, when fully understood, be met with such artificial checks, as may render them comparatively harmless. And in future, we probably must submit to diseases which we have brought out for special purposes, and curb them by checks that they do us little harm; as we submit to smut, ergot, &c. in our grain crops; and small pox, &c. among ourselves; and be thankful, that when we work with too much steam, we can either open the safety valve for its escape, or apply the governor to regulate, as we wish, all its movements.

The turnip is cultivated to provide a supply of fresh food for cattle during the winter months, and render less necessary the growth of so much grass in summer as, being made into hay, will maintain the cattle during the winter. The value of the turnip crop for such a service will therefore depend upon quality, as well as quantity. The roots of all biennial plants are intended by nature for storing up provisions for the fertilisation of the ovules, and maturation of the seed during their second season of growth; and they continue to store up such provisions, as long as the roots increase. The period of growth or increase of roots will vary with the season, and the variety of turnip cultivated; yet, in no season will be later than the end of November. So far as quantity of food then is concerned, turnips will be ready for gathering by that time. And if we test the quality, we shall find that it also remains unaltered during the winter months, until the bulbs begin to sprit in the following season. In gathering turnips therefore, they should all be so stored as to preclude the possibility of spritting during their season of repose. And this may be done by keeping them cool during the winter, either by placing them in thin strata under fences, and so covering them as to keep out the

frost. Storing them in heaps is as absurd as so storing potatoes. In root houses, they ought to be kept cool and dry. Care also should be taken in gathering them, not to cut off the tap root too near to the bulb, and to leave a portion of the collet, in which is seated their vital energy above, lest the agents of decomposition be let in, and the bulbs rot during the winter. Loads of turnips are lost to the cultivator, every year by the carelessness of servants, &c. in gathering them *in this way*. In open and mild autumns, some varieties of the turnip, especially of the Swede turnip, if sown early in May, have a tendency to throw up stems for flowering and seed. Whenever this tendency is observed, the crop ought to be gathered immediately. For not only do the bulbs cease to grow, when this change takes place, but they deteriorate greatly in nutritive properties. The vascular tissues form rapidly at the expense of the fluids in the cellular tissues. And as all vascular tissue is unfit for food, and is thrown out of the animal system unchanged in the excrement; the great loss and injury sustained in such a case, must be very apparent. If the turnips be left in the ground during winter, and gathered for consumption as they are wanted, the tops should be cut off before the frost arrives,

and the plough drawn between the drills, to throw up a slight covering of the soil over the bulbs, as in the south of France, as a protection against the inclemency of the season.

What is true of the turnips in particular, as an article of food, is true with regard to beet root, mangel wurtzel, carrots, parsnips, &c. in general; each one, and all kinds must be secured as soon as vegetation ceases; and before any change previous to fertilisation and fructification is evident; similar care being bestowed in storing them, to prevent any vital action from commencing, or any decay from arising among them.

Our subject just points out to us another provision of nature of which we ought to take advantage, and that is, the maturing and gathering of turnip and biennial seeds for sowing. The natural dissemination of such seeds is by scattering them over the soil, where they remain inert during the winter. The soil is hence their proper receptacle, and not the air in which we keep them. And as such seeds are furnished with oleaginous matter, to protect them against the effects of moisture within the soil, and such matter is more or less dissipated by the air, we

ought to keep all such seeds in their pods or husks during the winter, that the action of the atmosphere may be excluded from them. And if we gather the pods, ere full maturation supervenes, the seeds will be better adapted for germination, and less liable to be shed from accidents. Farmers know, that turnip seed if left carelesly exposed to the air, and kept one year, fails in a great measure to germinate. And when they know the reason, they not only will not run such risks as to sow such seeds, but will carefully guard against such injuries, as may in the least check the vigorous germination of their seeds, since under such circumstances the seedling plants are, too frequently exposed to the attacks of insects during their germinative stage of growth.

The advantages pointed out by physiology on the present subject may be objected to, as scarcely appreciable, and therefore of no moment. All natural processes are of this kind. The mass is made out of minims. And if manufacturing prosperity consists of vast returns, resulting from small profits, why should not agricultural prosperity be built upon a similar basis? Produce must be increased in every possible way; and that produce secured to the most profitable end. So that

he who guides the loom in the manufactory, to produce fabrics of the most subtil texture, with the most consummate skill, and ekes out his recompense from farthings and half farthings, accumulating by thousands; and he who guides the never-tiring loom of nature, must pursue the self-same plan, and out of the secret processes of the same, which meet not the eye of the looker on, find his reward in the vast aggregation of very small advantages. If we mean to farm well, we must employ our capital in encouraging produce, to extend itself in every minute particular, and then so secure that produce, that not a particle of its value be lost to us, as the producers, nor to the community as consumers.

IX.—*On Physical Data, applicable to Mathematics, in the Science of Meteorology, Hydrodynamics, Heat, &c.* By Robt. Rawson.

(Read October 5, 1847.)

The collection of physical data has been at all times, considered an important part in the successful prosecution of natural knowledge; no great advancement can be hoped for without it, either in the laws which regulate the operations of nature, or in the combining together of those laws in such a manner, as to establish completely a theory, by means of which we can explain the various and complex, yet harmonious, phenomena which are frequently presented to our senses.

This part of the labours of the inquiring votary of science has assumed a more important aspect since the time of the Novum Organum, and the successful application (of the method which Lord

Bacon recommended) by *Newton* in the mathematical principles of natural philosophy. In this work we find, for the first time, a law of nature discovered by a cautious induction of a great variety of phenomena; and then, from this simple law, by an unequalled sagacity in the application of abstract science, Newton has succeeded in explaining the greater part of those interesting questions which had engaged the attention of mankind from the earliest ages of civilization; and by this means he has laid the foundation of Physical Astronomy on a basis which never can be shaken, however much the superstructure may be modified by subsequent inquiry. It is true that Kepler established the three primary laws which regulate the motion of the planets, by a laborious process of observation, the results of which he combined with great skill and ingenuity; but it was reserved for Newton to refer these laws to one great principle, from which he was enabled to deduce the motions of the solar system. In consequence of the success which attended the labours of Newton, in that part of his speculations concerning the application of abstract science to the data obtained by careful observation, other efforts have been made with more or less success, having the same object in view which Newton

had in his immortal work. The importance of collecting accurate and efficient data, in order to establish correct theories in physical science, is at once apparent; this view has induced me to consider what data is required in some of the less perfect branches of physical science, to enable the mathematician to compute with certainty the time, manner, &c. of any particular event, which may occur in the ordinary course of nature.

The subjects which have engaged my attention, are the following, which I shall separately discuss, Meteorology, Hydrodynamics, Heat, &c.

Meteorology is greatly indebted to our late president, Dr. Dalton, for many valuable observations, and particularly for his admirable explanation of the phenomena of rain &c.

The following consideration, I think, ought to guide us in the selection of data, to be applied, by means of abstract science, to the explanation of facts which we daily observe; *if we discover, by patient investigation and research, that the object of our constant meditations is possessed of a property, either peculiar to itself or common to other objects, then we should endeavour to*

ascertain, by all the means we have at our command, the degree of this property, and what are the circumstances which regulate its action and preserve its continuance.

Thus we find that a rigid body is held together by means of attractive forces, which act upon matter imperceptibly, their effects only become apparent to our senses;—that these secret forces do act upon matter, and in many cases with considerable power, we know from the circumstance of applying an opposite force, in order to cancel their effects.

The next enquiry is, respecting this property of attractive forces, to find the amount of them, under every variety of circumstance, that gives to material bodies their rigidity; which greatly facilitates the translation of matter from one place to another. If we extend our enquiries we may combine the particular amounts of force, which is required to disengage rigidity, in such a manner as to elicit from them the laws which govern their action during the time from whence rigidity commences, to the time of attaining its maximum action, and then again, to the time when rigidity ceases. To prosecute our

researches thus far, they would be attended with great labour and expense; the latter prevents entirely the more humble inquirer after nature's truths, from being able to hold a communion with those truths that are far removed from the ordinary observations of man.

A beautiful exemplification of this mode of obtaining from nature her profound, yet simple treasures, may be found in the writings of Dr. Dalton. In his Meterological observations, page 18, he states that "one universal effect of fire, is its expanding or enlarging those bodies into which it enters, which bodies subside again when the fire is withdrawn." He further states, in the same page, that "*Solids* are least expanded by it, *inelastic fluids*, as water, spirits, &c. &c. more expanded, and elastic fluids, as air, most of all." Knowing this he was led to enquire into the amount of expansion of gases, when subjected to the same pressure, and receiving different degrees of heat. This investigation terminated in the establishment of a law, which is, that gases under the same pressure receive equal expansions for equal increments of temperature, and always expansions proportional to the temperature. Many similar examples might be given from the history of natural philosophy.

The Rain Gauge is an instrument adapted to ascertain the amount of rain deposited in the locality where it is placed, and for many purposes connected with the trade and commerce of this country, the average amount of rain, which falls at different places, is very desirable and useful to know; in connection with an accurate acquaintance with the geological deposition and chemical properties of the strata on which it falls. But for philosophical purposes, it appears to me to be desirable to ascertain, not only the amount of rain which falls, but the outline of the space in which rain is descending, and the direction and force of the wind.

With respect to the variations of the Barometer, there appears to be a great variety of opinions amongst the cultivators of meteorological science; these I shall pass over, and proceed to state the elements which, I conceive, ought to be carefully observed. Hitherto, observations have been conducted principally with a view to discover the relation between the amount of water disengaged from the atmosphere, and the weight of a column of atmospheric air, no relation however between these two elements has yet been determined. The time during which the mercury

moves from one point of the barometer to another should be noticed, and no doubt there is a relation between the time in which the variation of the barometer takes place, and the time of transmission of fluid pressure through the atmosphere, from one point to another. The observation of the element of time, readily suggests itself from the circumstance that no alteration can take place in the weight, and consequently in the pressure of the atmosphere, only by means of adding to, or taking away material particles from it; this appears to be so much in accordance with our notions of the doctrine of abstract forces, that few deny the truth of it. It is true, that if the variations of the weight of the atmosphere is the cause of the fluctations of the barometer, we ought to have the mercury falling during the time that the rain is descending; this is not always found to be the case, the barometer sometimes rises during the time that rain is falling; this circumstance may be produced by the dis-disturbance of the atmosphere at a considerable distance from the place where the barometer is situated.

Additions to the weight of the atmosphere at any place on the earth's surface can only be made

by means of three sources; the first is, that heat, by being unequally diffused over the earth, will drive the particles of air from the place where it predominates to other places where the heat is not so intense; by this means the barometrical pressure is disturbed. The second is, that the atmosphere becomes loaded with vapour, which *rises* from the surface of the earth; this evaporation takes place unequally on the earth's surface, and the vapour is carried over it by means of currents of wind; the atmosphere becomes disburthened from this weight of vapour, by means of its conversion into water, which falls to the ground. The next source is, that the lower part of the atmosphere may be overloaded by having an undue share of oxygen, arising from the escape of that gas, from the various products of vegetation, more freely at one time than another. This will agree with the idea expressed by Dr. Dalton in his Meteorological Essays, p. 98, where he states, in reference to the variation of the barometer, "that the whole or greater part of the variation is occasioned by a change in the density of the lower regions of the air." This great man, in his exposition of the different theories which have been proposed by various philosophers, to explain the fluctuations

which take place in the weight of the barometrical pressure in the different latitudes of the earth's surface, has fully and satisfactorily explained the circumstance of the barometer rising when the rain is falling, and falling when evaporation is going on. He states that, "it must be allowed that water, when changed into vapour, constitutes a part of the atmosphere, for the time, and weighs with it accordingly; also, that when vapour is precipitated in form of rain, the atmosphere loses the weight of it. But it would be too hasty to conclude from hence, that where evaporation is going forward the barometer must rise, and where rain is falling it must fall also; because air loaden with vapour is found to be specifically lighter than without it. Evaporation, therefore, increases the bulk and weight of the atmosphere at large, though it will not increase the weight over any particular country; if it displace an equal bulk of air specifically heavier than the vapour, and in like manner, rain at any place may not diminish the weights of the air there, because the place of the vapour may be occupied by a portion of air specifically heavier."—(See Dr. Dalton's Meteorological Essays, p. 96 and 97.)

How far each of these individual causes conspire to produce the variation of the barometer is a question of extreme difficulty to answer. The following are the data which seems to me to be desirable to obtain in order to give a full and explicit exposition to the above inquiry.

1st. As the extreme limits of the barometer are obtained, often with great rapidity, the time of obtaining its maximum and minimum points, with the time those points remain stationary, should be constantly observed at different points on the earth's surface.

2nd. That when evaporation takes place, either from the surface of land or from water, the total quantity of evaporation, with its density at any temperature, ought to be carefully ascertained.

These are amongst the data which ought to be taken in order to enable the mathematician to give a solution to the following problem :

Given the initial circumstances of the atmosphere at any epoch, together with the laws which regulate the transmission of fluid pressure from

one point to another, to find the state of the atmosphere at any other time.

Intimately connected with the data of this question is the science of Hydrodynamics, or the motion of fluids.

The theory of Hydrodynamics has been cultivated by most modern philosophers, since the time that Newton gave his researches on the motion of bodies in fluids resisting as the square of the velocity. There is an able report on the recent investigations in Hydrodynamics, by G. G Stokes, M.A. published by the British Association for the advancement of science. No one can read with satisfaction the mathematical investigation of the general equation of fluid motion, as given by Poisson in his Mecanique, and Moseley in his work on Hydrodynamics, in consequence of quantities being neglected in the course of the process, whose ultimate influence, if carried on, cannot be foreseen. After two such steps, as neglecting quantities, Poisson arrives at an equation which he supposes to express the law of continuity of the fluid, and which must vanish, or be equal to nothing in the case of an incompressible fluid. There is no wonder why

the results of such investigations, made in the manner described, should be so much at variance with what actually takes place in nature. This circumstance no doubt led Sir John Leslie to remark, "The profound researches of Lagrange and Poisson on the vibrations of fluids, are only fine speculations, which yet seem to bring out no definite or practical results." (See notes to Natural Philosophy.)

The main points of enquiry in this branch of human knowledge are; 1st. To determine the amount of resistance of the fluid to the motion of a rigid body of any shape. 2nd. To determine the motion of a rigid mass entirely immersed in two fluids of different specific gravities, each fluid having currents making a given angle with each other. 3rd. To find the velocity with which fluids when subject to a given pressure, issue from the orifice of vessels.

These questions are among the most important ones in this science, to which our attention and efforts should be directed.

In point of utility, the first of these questions is obvious, since the motion, both of rotation and

translation, of all rigid bodies, is affected by the resistance which the fluid opposes to their progress. The second question is one closely connected with the naval architecture of this great country, since vessels are supported in two fluids, water and air, whose specific gravities are as 1 to $\frac{1}{800}$. Instead of vessels being urged by means of the currents of winds, the effects of which being collected by means of strong canvass to a certain point, it is now becoming customary to urge them on by means of the screw propeller, which acts on the vessels at a point very different from the resulting accumulation of atmospheric currents. With respect to the screw propeller, there have been numerous experiments made, some by private individuals, and others by the government, in order to ascertain, if possible, the best form of screw for propelling the vessel through the water with the greatest possible velocity. Inquiries of this nature ultimately led our ingenious associate, Professor Woodroft, to invent and adopt a screw with a varying pitch, which has succeeded much better than the screw with a constant one, in effecting the object for which it is proposed.

There is little doubt but the relative motion of

translation of the vessel, and rotatory motion of the screw, will be effective in giving the greatest amount of motion of translation in the direction of the vessel's motion. This relation would again depend upon the resistance which the thread of the screw met with in its progress through the water.

The third question has its application in the conveyance of water through pipes, in order to supply large towns with a quantity of water adequate to their demands.

The data required from actual observation in order to give a solution to the above questions, are of a very complex and intricate nature, and can only be obtained by means of extensive experiments, devised with great judgment, and well conducted. The apparatus necessary for the prosecution of such speculations, can only be obtained at a great expense, which necessarily prevents many, amongst the most earnest and anxious enquirers, to know something of the nature of those laws which operate in producing such rapid and prodigious variations in the material world, from pursuing their enquiries into the more distant, and consequently less frequented,

parts of nature's dominion. I would fain hope that when the desirableness of imparting to the youth of this country sound information, by extending and developing the privileges of education, is seen, we shall then have opportunities offered by the government to enable us to contemplate the secret and profound recesses of nature.

The forces which oppose the progress of a rigid body in a fluid are; 1st. The friction of the fluid on the surface of the body. 2nd. The friction of the particles of water rubbing against each other. 3rd. The number of fluid particles disturbed by the motion of the rigid body. The resultant of these three forces will be the resistance which the rigid body will meet with in its progress through the fluid.

Hence the data required, in the first place, to find the amount of friction of a fluid rubbing against a solid body. I know of no experiments which have been devised or made, having this object in view, and it is an element of great importance, not only in molecular action, but in the immense oscillations which large vessels in our navy so often experience, when they are subjected

to the powerful influence of large waves of water and currents of wind. Euler, and all succeeding writers on the stability of floating bodies, make the following principle the foundation of their enquiries, namely, that when a vessel is acted upon by the horizontal force of the wind, the vessel will turn round on a line which passes through the centre of gravity of the body, while the centre of gravity remains at the same distance from the plane of flotation. This principle would not be true, I believe, even if there was no friction between the water and the sides of the vessel, but there is, and to what extent, experiment only can determine: the water in the case of a vessel floating forms an inclined plane, and the friction of the plane will prevent the vessel from sliding down it with that freedom which the vessel would do providing there was no friction whatever. This defect in the theory of the stability of vessels, was first pointed out by Professor Moseley. In order to ascertain the distance of the line round which the vessel oscillates from the plane of flotation, it will be requisite to obtain from experiments the amount of the resultant of the wind's force, and the point where it acts upon the vessel, and also, the same with respect to the resistance of the

water, together with the friction of the water on the sides of the vessel. In the second place, the data required is to obtain the limits of disturbance of the fluid mass, which I shall call the *solid of disturbance*. This is an essential and important element in the investigation of fluid motion, in consequence of its connexion with the theory of the transmission of sound. The time should be carefully obtained in which the initial disturbance of the fluid reaches the confines of the solid of disturbance. The law connecting these elements with the pressure which produces the fluid motion, and also the law which regulates the transmission of the pressure, can only be obtained by a numerous and well-conducted set of experiments.

There is another important datum which is closely connected with the naval architecture of this country—it is this: when the canvass is employed to collect the force of the wind, the point where the resultant will pass through, for currents of varying intensity, should be well ascertained. These I conceive to be amongst the most important parts of the data which are required to apply mathematics to the science of Hydrodynamics.

Heat, or Caloric is the next subject of importance, and is second to none in the Physicomathematical sciences, both in point of usefulness and difficulty, which a close investigation into its origin and nature will inevitably lead us to. Whether material particles are kept asunder by means of the repulsion of their caloric, or by means of a property which the particle of matter may possess, of changing the resultant of its attractive energy at some point, not very distant from itself, appears to be difficult to determine. This arises in consequence of the subtlety of the operation, which entirely eludes the constant exertion of our senses. The complete determination, however, of this question would be attended with considerable advantage in the consideration of molecular action. If a particle of matter be surrounded with several smaller particles of caloric, which repel each other, but attract the particles of matter, whilst the particles of matter repel each other, a material body subject to pressure, large enough to overcome the repulsion of the caloric, would have its particles of matter in closer contact or union, and consequently would displace the particles of caloric which we find to accord with observation. Now, if these particles of caloric which are endued with a

repulsive force, be replaced by the particles of matter being compelled by a sufficient pressure to take a closer union, the quantity of caloric displaced ought to be proportioned to the density of the fluid.

The experiments necessary to ascertain the truth of this statement, must be, from the subtlety of the subject under consideration, very delicate; and consequently, the apparatus used for such purposes must be well constructed.

The forces of attraction and repulsion are intimately connected with all subjects of physical science, but more particularly the theoretical part of chemistry, when the phenomena which takes place in that science are considered to be the effects of molecular action.

The mineralogical variations which we perceive in the earth no doubt owe their origin to the chemical changes which the particles that compose them have been, at very distant periods of the earth's history, subject to. I mean by chemical changes, changes produced by means of the excess of one force which acts on a particle over another force; the effect, which is the motion

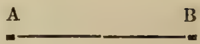
of the particle, is, I presume, decidedly mechanical. There is no doubt that heat, or caloric, has great influence in disturbing the equilibrium of the attractive and repulsive forces.

The attractive force which acts upon all bodies is mutual, and varies in its intensity reciprocally, as the square of the distance from the attractive particle to the attracted one; as was first distinctly stated and enforced by Newton, in his Principia, book iii. prop. 7, in consequence of the facility with which many of the phenomena observed in practical astronomy were explained. There are two ways in which this attractive, or central force, may be supposed to exist in every material particle; the first, which is the one above stated, where rays of force are supposed to emanate from the particle, in every possible direction, with a variable magnitude that is some function of the distance; and another way, which is, that the attractive forces which surround a particle are constant in intensity, and unlimited in the distance to which they exercise their influence. If we examine the effects of the latter of these two modes of considering attractive forces, the former being well known, we shall find that the law of gravitation and the inertia of bodies are a

consequence easily derived from it. It is not difficult to show that the quantity of rays of force which falls upon a material particle varies, as the square of its distance, from the centre of forces. Hence, as the same particle approaches the centre of force, the quantity of forces falling upon it will increase; at half the distance the forces will be four times as great, &c. As the rays of forces converge to a centre, they may be considered parallel for a small distance, which is the reason why bodies moving vertically near the earth's surface are uniformly accelerated.

If we conceive that a particle of matter is endued with a repulsive force, together with an attractive force, and that this repulsive force is constant in magnitude and unlimited in the distance to which it exercises its influence: there will not be any difficulty in showing that the effects of this constant repulsion will vary inversely as the square of the distance from the repelling particle.

Now if we propose to explain the finite extension of matter by means of the balancing of these attractive and repulsive forces, we shall find that it will be inadequate to the purpose.



Let a particle at A attract another at B with a force $\frac{C}{A\,B^2}$ and repel it at the same time with a force $\frac{C^1}{A\,B^2}$, where C, C^1 are the absolute forces of attraction and repulsion when the distance A B is equal to unity.

Then the effective force of A on B will be the difference of the attractive and repelling forces, viz.

$$\frac{C}{A\,B^2} \backsim \frac{C^1}{A\,B^2} = \frac{C \backsim C^1}{A\,B^2}$$

This result shows that when the constant C is greater than C^1 then the attractive force is greater than the repelling force and will always continue to be so, and if C^1 be greater than C the repelling force will be greater than the attractive and will always continue greater. Hence the force which acts upon the particles A & B by their mutual attractions and repulsions according to the above law will not account for their extensibility. The same kind of reasoning as the above will show that when the attractive and repelling forces are the same function of the distance the attractive force if greater or less than the repelling force at any one point, it will continue to be so.

If we suppose that the intensity of each individual ray of force emanating from the centre of the material particle, to vary as any function of the distance, namely $f(x)$, where x is the distance of the attracting particle from the attracted: and also the repelling force to vary by the same law. Then we shall have $\frac{m\,f(x)}{x^2}$ for the attracting force at x, and $\frac{m^1 f(x)}{x^2}$ for the repelling force at x; where $m\,f(1)$ is the attractive force at a unit of distance and $m^1 f(1)$ is the repelling force at a unit of distance. We shall have for the effective force of one particle on the other,

$$\frac{m\,f(x)}{x^2} \backsim \frac{m^1 f(x)}{x^2} = (m \backsim m^1)\,\frac{f(x)}{x^2}$$

To determine the point C where the two forces are equal we must substitute $AC = p$, for x in the eqation $m\,f(x) = m^1 f(x)$
from which we have,

$$m\,f(p) = m^1 f(p)$$
$$\therefore\ (m - m^1)\,f(p) = 0$$
$$\text{or } f(p) = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

To find the motion of two bodies subject to forces varying by means of the above law,

Let M & M^1 be the masses of the bodies A & B respectively $0A = x$ & $0B = x^1$

0 being a fixed point in the line A B produced $t =$ time the bodies arrive at distances x and x^1 respectively.

The effective force of A upon B is $(m \backsim m^1)\dfrac{f(x^1-x)}{(x^1-x)^2}$

Ditto B upon A is $(m \backsim m^1)\dfrac{f(x^1-x)}{(x^1-x)^2}$

$$\therefore M\frac{d^2x}{dt^2} = (m \backsim m^1)\frac{f(x^1-x)}{(x^1-x)^2} \quad\text{.....................}\quad (2)$$

$$\& \; M^1\frac{d^2x^1}{dt^2} = -(m \backsim m^1)\frac{f(x^1-x}{(x^1-x)^2} \quad\text{..................}\quad (3)$$

by the equations of motion.

Add together equations (2) and (3), and we shall have

$M\dfrac{d^2x}{dt^2} + M^1\dfrac{d^2x^1}{dt^2} = 0.$ Integrate this equation with respect to t, and we shall have

$$M\frac{dx}{dt} + M^1\frac{dx^1}{dt} = C \quad\text{..................}\quad (4)$$

Where C must be determined from the initial circumstances of motion. Put v and v^1 to repre-

sent the velocities of A and B at distances a and a^1 respectively.

$$\therefore C = M v + M^1 v^1$$

Consequently equation (4) may be written

$$M \frac{d x}{d t} + M^1 \frac{d x^1}{d t} = M v + M^1 v^1 \quad \ldots\ldots\ldots (5)$$

Integrate this equation, and we have

$$M x + M^1 x^1 = (M v + M^1 v^1)\, t + C^1 \ldots\ldots\ldots (6)$$

To determine C^1, we have the values of x and x^1 when $t = 0$

$$\therefore M a + M^1 a^1 = C^1 \text{ ; consequently}$$

$$M x + M^1 x^1 = (M v + M^1 v^1)\, t + M a + M^1 a^1 \ldots\ldots (7)$$

If X be the distance to the centre of gravity of M and M^1 at any time t; and A be the distance of the centre of gravity at the commencement of motion, we shall have

$$M x + M^1 x = (M + M^1)\, X$$

$$M a + M^1 a^1 = (M + M^1)\, A$$

Substitute these values in equation (7), and we shall have

$$X - A = \left(\frac{M\,v + M^1\,v^1}{M + M^1}\right) t \quad \ldots\ldots\ldots\ldots (8)$$

When v and v^1 are nothing, we shall have

$$M\,x + M^1\,x = M\,a + M^1\,a^1 \quad \ldots\ldots\ldots\ldots\ldots (A)$$

Hence, the motion or the space which the centre of gravity moves through is proportional to the time.

If we consider $M = M^1$; we shall have

$$X - A = \frac{v + v^1}{2} \,.\, t \quad \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Let us next examine the equation (1) viz. $f(p) = 0$

$$\text{Put, } f(p) = p^2 + n_1 p + n_2 = 0$$

$$\therefore\ p = -\frac{n_1}{2} \pm \frac{\sqrt{n_1^2 - 4\,n_2}}{2}$$

Hence there are two values of p, namely

$$\frac{-\,n_1 + \sqrt{n_1^2 - 4\,n_2}}{2} \text{ and } \frac{-\,n_1 - \sqrt{n_1^2 - 4\,n_2}}{2}$$

Equation (8) contains the conclusion arrived at by Newton. See Principia, page 27, vol. 1.

where the bodies will remain at rest, if they are placed there when they are not in a state of motion.

Since, $f(x) = x^2 + n_1 x + n_2$, is the law of force of each ray: substitute this value in equations (2) and (3) and we shall have for the equations of motion—

$$M \frac{d^2 x}{d t^2} = (m \backsim m^1) \left\{ \frac{(x^1 - x)^2 + n_1(x^1 - x) + n_2}{(x^1 - x)^2} \right\} \ldots (10)$$

$$\& - M \frac{d^2 x^1}{d t^2} = (m \backsim m^1) \left\{ \frac{(x^1 - x)^2 + n_1(x^1 - x) + n_2}{(x^1 - x)^2} \right\} \ldots (11)$$

These equations may be written

$$\frac{d^2 x}{d t^2} = \frac{(m \backsim m^1)}{M} \left\{ 1 + \frac{n_1}{x^1 - x} + \frac{n_2}{(x^1 - x)^2} \right\} \ldots (12)$$

$$-\frac{d^2 x^1}{d t^2} = \frac{(m \backsim m^1)}{M^1} \left\{ 1 + \frac{n_1}{x^1 - x} + \frac{n_2}{(x^1 - x)^2} \right\} \ldots (13)$$

Add equations (12) and (13), and we shall have

$$-\frac{d^2}{d t^2}(x^1 - x) = \left\{ \frac{(m \backsim m^1)}{M} + \frac{(m \backsim m^1)}{M^1} \right\} \left\{ 1 + \frac{n_1}{x^1 - x} + \frac{n_2}{(x^1 - x)^2} \right\}$$

Multiply by $2 \frac{d(x^1 - x)}{d t}$ and integrate

$$-\left(\frac{d(x^1-x)}{d\,t}\right)^2 = 2\,(m \backsim m^1)\left\{\frac{1}{\mathrm{M}}+\frac{1}{\mathrm{M}^1}\right\}\left\{(x^1-x) - n_1 \log.\,(x^1-x) - \frac{n_2}{(x^1-x)}\right\} - 2\,\mathrm{C}$$

when $(x^1-x)=(a^1-a)$ we shall have $\dfrac{d(x^1-x)}{d\,t}=0$

$$\therefore\ \mathrm{C} = (m \backsim m^1)\left\{\frac{1}{\mathrm{M}}+\frac{1}{\mathrm{M}^1}\right\}\left\{(a^1-a) - n_1 \log.\,(a^1-a) - \frac{n_2}{a^1-a}\right\}$$

Hence, we have

$$\frac{d(x^1-x)2}{d\,t^2} = 2\,(m \backsim m^1)\left\{\frac{1}{\mathrm{M}}+\frac{1}{\mathrm{M}^1}\right\}\left\{n_1 \log.\,(x^1-x)\,(a^1-a) + n_2\left(\frac{1}{x^1-x}+\frac{1}{a^1-a}\right) - (x^1-x) - (a^1-a)\right\} \ldots\ldots (14)$$

This is the square of the velocity with which the particles approach or recede from each other according as m is greater or less than m_1.

Again, let the law of force, $\mathrm{f}(x) = n_1 + n_2\,x + n_3\,x^2 + n_4\,x^3 +$ &c. &c. be taken.

Then the roots of the equation

$n_1 + n_2\,x + n_3\,x^2 +$ &c. $= 0$ will determine so many points where equilibrium will take

place among the particles. Substituting the value of $f(x)$ in equations (2) and (3), we shall find the volocity with which the particles approach or recede according as $m > m^1$ or $m < m^1$.

The points of equilibrium here mentioned are not produced by means of the antagonist forces of attraction and repulsion, but they are points at which both the attraction and repulsion are equal to nothing.

Let us now proceed to investigate the subject in a more general manner, by proposing different Laws for the attractive and repulsive forces.

Let a particle M placed at A, attract and repel a particle M^1 placed at B, with forces which vary as $m\ f(x)$ and $m_1\ \Phi(x)$ respectively. Where the distance A B is represented by x.

By referring to page 351, we shall find that

$\frac{m\,f(x)}{x^2}$ = the effective attractive force of A on B.

$\frac{m^1\,\Phi(x)}{x^2}$ = the effective repelling force of A on B.

Hence, the two particles M and M^1 will approach, be at rest, or recede from each other, according as the following conditions are complied with respectively, namely,

$$m\,\frac{f(x)}{x^2} > m^1\,\frac{\Phi(x)}{x^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

$$m\,\frac{f(x)}{x^2} = m^1\,\frac{\Phi(x)}{x^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$$

$$m\,\frac{f(x)}{x^2} < m^1\,\frac{\Phi(x)}{x^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (17)$$

These equations reduce to the following,

$$m\,f(x) > m^1\,\Phi(x) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (18)$$

$$m\,f(x) = m^1\,\Phi(x) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

$$m\,f(x) < m^1\,\Phi(x) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$$

If the condition (18) is complied with we shall have $\frac{m\,f(x) - m^1\,\Phi(x)}{x^2}$ = the effective attractive force of A on B .... (21)

And if the condition (19) is complied with we shall have $\frac{m\,f(x)}{x^2} = \frac{m^1\,\Phi(x)}{x^2}$ .... (22)

And if the condition (20) is fulfilled we shall have $\frac{m^1\,\Phi(x) - m\,f(x)}{x^2}$ = the effective repulsive force of A on B .... (23)

There are several values of x, which are the roots of the equation $m\,\mathrm{f}(x) = m^1\,\Phi(x)$, that will satisfy the equation (22), and consequently for each of these values of x there will be an equilibrium between the two forces of attraction and repulsion.

The equations of motion of the two particles A and B will be,

$$\mathrm{M}\frac{d^2 x}{d t^2} = \frac{m\,\mathrm{f}(x^1 - x) - m^1\,\Phi(x^1 - x)}{(x^1 - x)^2}, \text{ for A's motion (24)}$$

$$-\mathrm{M}^1\frac{d^2 x^1}{d t^2} = \frac{m\,\mathrm{f}(x^1 - x) - m^1\,\Phi(x^1 - x)}{(x^1 - x)^2}, \text{ for B's motion (25)}$$

for the attractions, where x and x^1 are the coordinates of A and B respectively at any time t and measured from a fixed origin in the line joining A and B.

To the equations of repulsive motion we have

$$\mathrm{M}\,\frac{d^2 x}{d t^2} = \frac{m^1\,\Phi(x^1 - x) - m\,\mathrm{f}(x^1 - x)}{(x^1 - x)^2}, \text{ for the motion}$$

of A from B .... (26)

$$-\mathrm{M}^1\,\frac{d^2 x^1}{d t^2} = \frac{m^1\,\Phi(x^1 - x) - m\,\mathrm{f}(x^1 - x)}{(x^1 - x)^2}, \text{ for the motion}$$

of B from A .... (27)

In both of the above cases of motion the centre of gravity will move uniformly, so that the relation of x^1 to x, will be of the form $x^1 = \mathrm{N} + \mathrm{N}^1 x$ N and N^1 being constant quantities.

Let us now examine equation (18) in order to find the values of x which will make $m\,\mathrm{f}(x) > m^1\,\Phi(x)$. At every value of x, which is a root of the equation $m\,\mathrm{f}(x) = m^1\,\Phi(x)$, there will be a change in the effective attractive and repulsive forces take place. Therefore the difficulty will be to assign the roots of the equation $m\,\mathrm{f}(x) = m^1\,\Phi(x)$. This equation, in the general form which we have put it, cannot have its roots determined only in particular cases.

We shall proceed, therefore, to investigate the preceding equations by giving particular values to the functions $\mathrm{f}(x)$ and $\Phi(x)$—

Let $\mathrm{f}(x) = \mathrm{P} + \mathrm{P}_1 x + \mathrm{P}_2 x^2$ and $\Phi(x) = \mathrm{P}_3 + \mathrm{P}_4 x + \mathrm{P}_5 x^2$ where $m\,\mathrm{P}_1 = m^1\,\mathrm{P}_4$ and $m\,\mathrm{P}_2 = m^1\,\mathrm{P}_5$ P_1; P_2 &c. &c. are all constants.

Then from equation (21) and (23) we shall have

$$\frac{m\,\mathrm{f}(x) \backsim m^1\,\Phi(x)}{x^2} = \frac{m\,\mathrm{P}}{x^2} + \frac{m\,\mathrm{P}_1}{x} + m\,\mathrm{P}_2 \backsim \left(\frac{m^1\,\mathrm{P}_3}{x^2} + \frac{m^1\,\mathrm{P}_4}{x}\right.$$

$+ P_5 m^1 \Big) = \dfrac{m P \backsim m^1 P_3}{x^2}$ the effective attracting or repelling force according as $m P$ is greater or less than $m^1 P_3$. Hence, if the attractive force is greater than the repelling force at any one point it will always remain greater. Therefore, this supposition of force will not account for the extension of material bodies.

If we suppose $m\,f(x) = P + P_1 x$ and $m^1\,\Phi(x) = P_2 + P_3 x$ without the conditional equations, then we shall have

$$\frac{m\,f(x) \backsim m^1\,\Phi(x)}{x^2} = \frac{P}{x^2} + \frac{P_1}{x} \backsim \left(\frac{P_2}{x^2} + \frac{P_3}{x}\right)$$

$$= \frac{P \backsim P_2}{x^2} + \frac{P_1 \backsim P_3}{x} \quad \text{............} \quad (28)$$

The effective attractive or repulsive force of A on B according as $\frac{P}{x^2} + \frac{P_1}{x}$ is greater or less than $\frac{P_2}{x^2} + \frac{P_3}{x}$

These forces are equal when

$\frac{P}{x^2} + \frac{P_1}{x} = \frac{P_2}{x^2} + \frac{P_3}{x}$. Multiply by x and we have $P + P_1 x = P_2 + P_3 x$

$$\therefore\ x = \frac{P_2 - P}{P_1 - P_3} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (a)$$

Therefore, when $x = \dfrac{P_2 - P}{P_1 - P_3}$, we shall have $\dfrac{P}{x^2} + \dfrac{P_1}{x} = \dfrac{P_2}{x^2} + \dfrac{P_3}{x}$, or the attractive force is equal to the repelling force.

If we substitute this value of x in either of the expression $\dfrac{P}{x^2} + \dfrac{P_1}{x}$, or $\dfrac{P_2}{x^2} + \dfrac{P_3}{x}$, we shall have the force to which however little is added, the sum will be sufficient to disturb the equilibrium of the two particles. Making this substitution we shall have

$$\frac{P}{x^2} + \frac{P_1}{x} = \frac{P(P_1 - P_3)^2}{(P_2 - P)^2} + \frac{P_1(P_1 - P_3)}{(P_2 - P)}$$

$$= \frac{P(P_1 - P_3)^2}{(P_2 - P)^2} + \frac{P_1(P_1 - P_3)(P_2 - P)}{(P_2 - P)^2}$$

$$= \left\{\frac{P(P_1 - P_3) + P_1(P_2 - P)}{(P_2 - P)^2}\right\}\left(P_1 - P_3\right)$$

$$= \frac{(P_1 P_2 - P P_3)(P_1 - P_3)}{(P_2 - P)^2}$$

$$= \left\{P_1 + P\frac{(P_1 - P_3)}{(P_2 - P)}\right\}\frac{(P_1 - P_3)}{(P_2 - P)}$$

This force will have to be overcome in order to move the particles in either direction, from or towards each other.

Taking the equations $\frac{P}{x^2} + \frac{P_1}{x} = 0$ & $\frac{P_2}{x^2} + \frac{P_3}{x} = 0$ we shall have from the first $x = -\frac{P}{P_1}$ and from the second $x = -\frac{P_2}{P_3}$, Therefore if the two particles be placed in the two points $-\frac{P}{P_1}$ distance from each other they will have no attractive influence whatever on each other: and if placed in two points whose distance from each other is $-\frac{P_2}{P_3}$ they will have no repulsive influence whatever on each other.

If we have the relation $\frac{P}{P_1} = \frac{P_2}{P_3}$, then the above phenomena will take place at the same distance of the two particles from each other.

These different states of equilibrium may possibly suggest some useful reflections on the characteristic difference between fluids and rigid bodies.

If the particles which compose a fluid mass be so situated as to have no attractive influence, then the least possible force will be sufficient to separate the particles, and enable them to move amongst each other with great facility, in the case of rigid bodies whose particles are in a state of rest with respect to each other; if the particles be placed so that the distance between them is equal to $\frac{P_2-P}{P_1-P_3}$, then the force

$\left\{P_1+\frac{P(P_1-P_3)}{(P_2-P)}\right\}\frac{P_1-P_3}{P_2-P}$ will have to be overcome, in order to disengage the regidity of the mass. Of course these are only speculations and proposed, (with great respect of the opinions of other cultivators of science,) by the writer as being, in his opinion, the probable cause of the constitution of material bodies.

If we add h to the above value of x, in equation (a), then A attracts B for all values of x greater than $\frac{P_2-P}{P_1-P_3}$

$$\text{if } \frac{P}{\left(\frac{P_2-P}{P_1-P_3}+h\right)^2}+\frac{P_1}{\left(\frac{P_2-P}{P_1-P_3}+h\right)}>\frac{P_2}{\left(\frac{P_2-P}{P_1-P_3}+h\right)^2}$$

$$+\frac{P_3}{\left(\frac{P_2-P}{P_1-P_3}+h\right)}$$

$$\frac{P}{\dfrac{(P_2-P+hP_1-hP_3)^2}{(P_1-P_3)^2}}+\frac{P_1}{\dfrac{(P_2-P+hP_1-hP_3)}{(P_1-P_3)}}>$$

$$\frac{P_2}{\dfrac{(P_2-P+hP-hP_3)^2}{(P_1-P_3)^2}}+\frac{P_3}{\dfrac{(P_2-P+hP_1-hP_3)}{(P_1-P_3)}}$$

$$\text{or } \frac{P}{\dfrac{(P_2-P+hP_1-hP_3)}{P_1-P_3}}+P_1>\frac{P_2}{\dfrac{P_2-P+hP-hP_3}{P_1-P_3}}+P_3$$

$$\text{or } \frac{P(P_1-P_3)}{P_2-P+hP_1-hP_3}>\frac{P_2(P_1-P_3)}{P_2-P+hP-hP_3}-(P_1-P_3)$$

$$\text{or } \frac{P}{P_2-P+hP_1-hP_3}>\frac{P_2}{P_2-P+hP-hP_3}-1$$

or $P>P_2-P_2+P-hP+hP_3$

or $hP>hP_3$

or $P>P_3$

Therefore, if P be greater than P_3, we shall have the attractive force of A on B greater than the repulsive force of A on B, for all values of x greater than $\frac{P_2-P}{P_1-P_3}$.

And, if P_3 be greater than P, we shall have the repulsive force greater than the attractive for

all values of x less than $\frac{P_2-P}{P_1-P_3}$, providing that the two curves represented by the equations

$$y = \frac{P}{x^2} + \frac{P}{x}$$

$$\& \ y = \frac{P_2}{x^2} + \frac{P_3}{x}$$

have not a common tangent at the point $x=\frac{P_2-P}{P_1-P_3}$

This condition may be determined by differentiating the above equations.

$$-\frac{dy}{dx} = \frac{3P}{x^3} + \frac{2P_1}{x^2}$$

$$-\frac{dy}{dx} = \frac{3P_2}{x^3} + \frac{2P_3}{x^2}$$

$$\therefore \ 3P + 2P_1 x = 3P_2 + 2P_3 x$$

$$\text{or } 3P + 2P_1 . \frac{P_2-P}{P_1-P_3} = 3P_2 + 2P_3 . \frac{P_2-P}{P_1-P_3}$$

$$3PP_1-3PP_3+2P_1P_2-2P_1P=3P_2P_1-3P_2P_3+2P_3P_2-2P_3P$$

$$PP_1-PP_3=P_1P_2-P_2P_3$$

$$\text{or } (P_1-P_3)P=(P_1-P_3)P_2$$

$$\text{or } P=P_2$$

Therefore, the condition $P = P_2$ will give a common tangent to the two curves at the point $\frac{P_2 - P}{P_1 - P_3}$.

There will be an equilibrium between two particles of the same kind which are attracted by the law $\frac{P}{x^2} + \frac{P_1}{x}$, and repelled at the same time by the law $\frac{P_2}{x^2} + \frac{P_3}{x}$. When the distance of the particles is $\frac{P_2 - P}{P_1 - P_3}$, the attractive force is effective when $P > P_3$ and $x > \frac{P_2 - P}{P_1 - P_3}$, the condition $P > P_2$ or $P < P_2$ must necessarily exist, otherwise the attraction or repulsion will prevail on both sides of $x = \frac{P_2 - P}{P_1 - P_3}$. If we extend this inquiry to the eqilibrium of three or more points in a straight line, we shall have a system of two or more equations which involve the respective distances when in a state of rest.

The formation of these equations is not difficult, but the determination of the distances between the particles will be a matter of great labour, as they will involve complex and intricate computation.

Let us now return to the laws $\frac{P}{x^2}+\frac{P_1}{x}$ and $\frac{P_2}{x^2}+\frac{P_3}{x}$ and assign particular values to the constants P, &c., &c.

We have shown that equilibrium exists when $x=\frac{P_2-P}{P_1-P_3}$.

Let $P_2-P=\frac{1}{1000}$ & $P_1-P_3=1$; at a unit of distance. Then the attractive force becomes $\frac{P}{x^2}+\frac{P_1}{x}$
And the repulsive force becomes $\frac{P+\frac{1}{1000}}{x^2}+\frac{P_1-1}{x}$

$\therefore x=\frac{1}{1000}=$ the distance at which equilibrium will take place. From the above equations we have $P_3=P_1-1$, and $P_2=\frac{1}{1000}+P$. Hence the condition $P>P_3$, becomes $P>P_1-1$; and $P>P_2$, becomes $P>\frac{1}{1000}+P$; which is always the case whatever be the value of P.

The effective attractive force is $\frac{P}{x^2}+\frac{P_1}{x}-\frac{P}{x^2}-\frac{1}{1000x^2}-\frac{P}{x}+\frac{1}{x}=\frac{1}{x}-\frac{1}{1000x^2}$, which is independent of P & P^1.

And the effective repulsive force is $\frac{P}{x^2}+\frac{1}{1000x^2}$

$+\frac{P_1}{x} - \frac{1}{x} - \frac{P}{x^2} - \frac{P_1}{x} = \frac{1}{1000x^2} - \frac{1}{x}$ which is also independent of the constants P & P_1.

Hence, the attractive or repulsive force predominates according as the distance between the particles is greater or less than $\frac{1}{1000}$.

The force which is required to disengage rigidity will be a little greater than $P.1000^2 + P_1.100$.

From what has preceded, respecting molecular forces and their mode of action, namely, by attraction and repulsion simultaneously, so that the material mass is entirely influenced and governed by the difference of these molecular forces, we shall be enabled to suggest, for future consideration, a new theory of aggregation and stability of material bodies, that will explain a great number of natural phenomena which have not been hitherto successfully explained by any of the theories proposed for that purpose.

NEW THEORY OF AGGREGATION.

If, as before stated, we denote the law of attraction of a particle of matter by $f(x)$; and the law of repulsion by $\Phi(x)$.

Then we shall have for the effective force of the particle

$$\frac{f(x)}{x^2} \backsim \frac{\Phi(x)}{x^2} = \frac{F(x)}{x^2}$$

$F(x)$ is a quantity which must be obtained by means of induction from many well conducted experiments upon particular material substances. It would be a matter of considerable difficulty to ascertain the law of attraction $f(x)$ and the law of repulsion $\Phi(x)$ in each individual particle of matter; but fortunately, the knowledge of these laws, so far as the motion of a body subject to the differences of their forces is concerned, can be of no use whatever, because $F(x)$ and $-F(x)$ will give the absolute forces of the particle when the attractive or repulsive forces prevail respectively.

Agreeably to what has been before stated, there are as many values of x that will make $\frac{f(x)}{x^2} - \frac{\Phi(x)}{x^2} =$ to nothing, as there are roots of the equation $F(x) = 0$.

Hence, at each of these values of x, which we shall call x_1, x_2, x_3, &c. &c., an equilibrium will take place; or two particles placed respectively at distances x_1, x_2, x_3, &c. &c. from each other will have no tendency to approach or recede.

This circumstance, or property of the roots of equations, will explain, beautifully, the reason why the same material particles combine in various proportions, and by that means produce combinations which possess various and distinct properties.

Chemical union I shall propose to call *Chemical equilibrium*, which takes place when the particles of matter are forced into the different roots of the equation $F(x)=0$.

The forces required to overcome the attractive force when disturbed by a small quantity h after

chemical equilibrium takes place, will be represented by $\frac{F(x_1+h)}{(x_1+h)^2}$; $\frac{F(x_2+h)}{(x_2+h)^2}$ &c. &c. &c., which we shall call the forces of rigidity of the material particles when they are placed at distances (x_1+h), (x_2+h), &c. from each other respectively. These molecular attractive forces must be small in all fluids, when they are at an ordinary temperature: for water below thirty-two degrees they increase, although the particles are compelled to take different roots of the equation $F(x)=0$.

The force required to overcome the repulsive force when chemical equilibrium takes place, will be $-\frac{F(x_1-h)}{(x_1-h)^2}$; $-\frac{F(x_2-h)}{(x_2-h)^2}$ &c. &c. &c., which we shall call the forces of compression.

These forces are great in water at all temperatures above thirty-two degrees of Fahrenheit.

Hence, for the compressive force of bodies to be equal to the tensile, we must have the conditions

$$F(x_1)=-F(x_1)$$
$$F(x_2)=-F(x_2)$$
$$F(x_3)=-F(x_3)$$
&c. &c. &c.

These conditions must be fulfilled in all material bodies, in order that equilibrium may take place.

If the particles are, by the application of force, compelled to assume the position $x_1 - h$ where h is a very small quantity, then the force $-\frac{F(x_1-h)}{(x_1-h)^2}$ will be called the force of elasticity of the body. And if the compressive force is equal to the tensile at any distance h of compression and extension we must have

$$\frac{F(x_1+h)}{(x_1+h)^2} = -\frac{F(x_1-h)}{(x_1-h)^2}$$

Develop these by means of Taylor's theorem and we have

$$\frac{F(x_1)+\overset{\text{I}}{F}(x_1)h+\frac{\overset{\text{II}}{F}(x_1)h^2}{1\cdot 2}+\&c.}{(x_1+h)^2} = \frac{-F(x_1)+\overset{\text{I}}{F}(x_1)h-\frac{\overset{\text{II}}{F}(x_1)h^2}{1\cdot 2}+\&c.}{(x_1-h)^2}$$

By the binomial theorem we have

$$(x_1+h)^{-2} = x_1^{-2} - 2x^{-3}.h + \&c. \&c.$$

$$(x_1-h)^{-2} = x_1^{-2} + 2x^{-3}.h + \&c. \&c.$$

And because $F(x_1)$ and $-F(x_1)$ are each equal to nothing, we shall have

$$\left\{ \overset{\text{I}}{F}(x_1)h + \frac{\overset{\text{II}}{F}(x_1)}{1 \cdot 2} h^2 + \text{\&c. \&c.} \right\} \times \left\{ \frac{1}{x_1^2} - \frac{2h}{x_1^3} + \text{\&c.} \right\} =$$

$$\left\{ \overset{\text{I}}{F}(x_1)h - \frac{\overset{\text{II}}{F}(x_1)}{1 \cdot 2} h^2 \text{ \&c.} \right\} \times \left\{ \frac{1}{x_1^2} + \frac{2h}{x_1^3} + \text{\&c.} \right\}$$

Since h is very small we may neglect the second and all higher powers of h, and then we shall have

$$\frac{\overset{\text{I}}{F}(x_1)h}{x_1^2} = \frac{\overset{\text{I}}{F}(x_1)h}{x_1^2}$$

That is, the compressive force is equal to the tensile force. This investigation explains why the forces of extension and compression are proportional to the distances compressed and extended, which was established by Tredgold and others. Professor Hodgkinson, F. R. S., M. R. I. A., &c. was the first to show that when the distances increased this law was not correct. I shall here leave the subject till some future opportunity.

X.—*Note on the employment of Electrical Currents, for ascertaining the Specific Heat of Bodies.* By J. P. Joule, Esq.

(Read July 13th, 1847.)

Having recently had occasion to ascertain the specific heat of sperm oil, I employed for the purpose the new method described in the Seventh Volume, New Series, of the Memoirs of this Society. Two platinum wires, each four inches long and $\frac{1}{100}$th of an inch in diameter, were immersed, one in a known quantity of water, and the other in the sperm oil. A powerful current of electricity from six large constant cells, was then transmitted through the wires for half an hour, and the increase of the temperature of the water and oil noted. The specific heat of the sperm oil arrived at was 0.3757, a result so much lower than that of Dalton, that I was led to examine whether I had fallen into any

error. For this purpose, I repeated the experiment, taking however the precaution to keep the liquid constantly agitated. The specific heat now came out 0.406. The cause of the smallness of the result became thus apparent. The oil could not carry off the heat from the wire as quickly as the water, and hence the wire which was immersed in the oil, became highly heated, occasioning an increase in its resistance, and a proportional increase in the quantity of heat evolved by it. This was easily proved, by placing the finger in contact with the wire, which could not be retained in that position longer than one or two seconds.

The object of this communication is therefore to guard the experimenter against employing wires of so small a surface, as those recommended in my paper on specific heat, whenever powerful currents are employed; especially when, at the same time, the specific heat of a viscous liquid of bad conductive power, and small capacity for heat, is sought. In such cases, a large strip of platinum foil would be preferable to a wire, on account of the extensive surface which would thus be presented to the liquid.

XI.—*On Water from Peat and Soil.* By R. Angus Smith, Ph. D.

(Read November 16th, 1847.)

In examining the water around Manchester, I perceived that the temperature had a great effect on that portion which came from peaty land. In warm weather the water becomes brown ; in cold weather it becomes perfectly pure. The water is very pure from the hills formed of sandstone, or rough rock, and frequently contains nothing more than from one to two grains of carbonate of lime in a gallon, with two grains of organic, *i.e.* peaty matter. When the warm weather begins, the streams become brown, and the colour is often very deep. Now we know, that the acids of the humus class are very insoluble in water, and, therefore, cannot form this deep solution of themselves. In a peat bog, which is not well drained, and is, therefore, wet and cold, the acids of the

peat do not become dissolved, so as to form a very deeply coloured solution. They form a solution of a pale yellow. But in grounds which are warmer, or what is better, well drained, the amount of soluble matter is very great. The colour of such water is not to be confounded with the water which heavy showers bring down, filled with mud and bits of peat. It is often perfectly clear and bright, but brown, like coffee. The acids, in solution at such times, are kept so by the presence of ammonia. Ammonia dissolves them in large quantities; and along with them also the salts which they form with lime, magnesia, soda, phospates, &c.

In the absence of heat, this ammonia is not formed; and grass, or other vegetables, do not grow. The great solvent power of ammonia led me to believe that its use must be more general than merely on a peaty hill. The same compounds found in heathy soil, are found in the most fertile soils, and the same ammonia is wanted to give them solubility. The quantity of ammonia put upon land, is much greater than can be absorbed by plants; but it renders the food of plants soluble, not the organic only, but the inorganic.

Plants begin to grow in warm weather, at this time ammonia is formed; it is at this time that the organic matter decays, and in its approach to inorganic matter, passes through the stage of ammonia. In doing so, it gives food and vigour to vegetation.

I mentioned in another paper, that whenever we examine the wells near cess pools, we get nitric acid. This is a further action of the same principle which produced ammonia, it is a further remove from organic nature. This is what occurs in nitre beds, and the same, of course, must occur in the neighbourhood of all heaps of manure, and in soils when decomposing. Vegetation must prevent the formation of nitric acid. The origin of ammonia on the hills is a curious point. If it comes from the atmosphere, it is, perhaps, merely a part of the same process which makes nitric acid, and the one is not more wonderful than the other. A very porous soil influences it greatly. This shows us the value of turning up land, and at the same time of draining, which is not a mere removal of water, but a passage of air, and of a liquid stream of food.

The peat-mould, Mulder has shown to be a salt

of ammonia, but he has not mentioned this excess of ammonia. From this fact we learn two or three things, and from the theory we are able to explain them.

Various opinions have been given of the value of peat as a manure; the peat water has also been used as an irrigator, and objected to by some. The distinction between alkaline and acid peat water will help to explain it: our important plants do not grow in acid soil.

Lime has been used to peat: this is easily explained, it sets the ammonia free, and the matters before insoluble dissolve in the excess of ammonia. The use of lime generally is also explained by it. Lime is used upon land which has more than it can ever use for plants, and it is used caustic, this sets ammonia free, and allows it to dissolve food for plants. Soda or other alkalis will serve the same purpose.

This note is a portion of a paper on water, which was read to the Society, but which will appear better afterwards on making such additions as may be more generally interesting.

XII.—*Description of an Aurora Borealis, seen at Kirkby Lonsdale, Westmorland, September 29th*, 1847. By William Sturgeon, Esq.

(Read October 19th 1847.)

A beautiful display of the Aurora Borealis was seen at this place, on Wednesday night, September 29th, 1847. The weather had been very fine during the whole of the day, and nothing unusual was observed, till after eight o'clock at night. Between eight and nine, however, a bright space in the heavens was observed to border the northern horizon, and soon afterwards a black curvilinear cloud encompassed its upper edge, having on its convex or upper margin, a bright glowing segment of a circle, concentric with the cloud within it. About nine o'clock, a few faint streamers shot upwards from the glowing bow. These first began on the eastern extremity of the bow, but shortly afterwards from every

part of it, increasing in splendour for several successive minutes; when, suddenly, the whole of the Aurora disappeared, as if extinguished by magic. The phenomena did not, however, terminate here: it seemed that the curtain dropped merely to show *the end of the first act.* In a few minutes a new piece was introduced, the character of which was not only very different to the former, but far superior in brilliancy and grandeur. The northern skies were now lighted up with a rapid succession of luminous waves, rolling upwards from nearly the horizon to the pole star. This display commenced a little after nine o'clock, and lasted till nearly ten. About the latter hour the brilliancy and frequency of the waves began to languish, and in less than half an hour afterwards, the Aurora had entirely disappeared, and was not seen to re-appear during the night.

On the following night, the Aurora Borealis appeared again: but in consequence of clouds, could only be seen at intervals, when they partially cleared away between the meteor and the observer. No streamers were observed, nor any other indication of an Aurora, beyond that of a strong light. A phenomenon of this kind

frequently appears the first night, and sometimes the second night also, after a grand display of the Aurora Borealis.

I have learned from the Rev. Mr. Abbot, and from some other gentlemen in this neighbourhood, that the Aurora Borealis has been frequently seen within the last two months. Since that seen on the 29th of last month, there have been no less than four or five displays of the meteor observed by myself. Last night (Oct. 13.) we had indications of a grand Aurora, as early as the setting of the moon, or shortly after sun-set. It turned out, however, to be but a very humble display, at least during my observation, which was till ten o'clock. A great number of streamers were observed, but their light was very feeble. The horizontal range of the Aurora was very extensive, but where its centre was situated I could not ascertain, because of the haze of light in which the streamers were seen. I have heard from a friend to-day, that the Aurora was very grand between twelve and one this morning.

Remarks.—It has been my opinion for a long time, that the Aurora Borealis is a traveller: and that its peregrinations are round the north pole

of the earth; or, perhaps, round its magnetic pole. The streamers, in some of them that I have observed, have had a *lateral* motion, a circumstance that attended the streamers of last night. And I find that an Aurora which I observed on the evening of September 3rd, 1839, in London, was seen in America on the same night, and, by *their* time, about the same hour, or somewhat earlier, so that it had travelled westerly (the direction in which the streamers moved as seen in London) at the rate of about 18° or 20° per hour, calculating from the time of its commencement here to its commencement in America: or, between nine o'clock in London to eight o'clock at Princeton.

I could not, however, from this solitary instance, suppose that the Aurora Borealis invariably travels in this direction, because I have seen streamers which travelled easterly; but those of last night travelled westerly. Nevertheless, if it can be proved that the meteor travels round some spot in high northern regions, or round the pole itself, an important step towards ascertaining the real cause of its appearance would be gained. That the Aurora Borealis is seen in widely different longitudes, is a fact long ago ascertained; and I cannot help think-

ing that many of those *steady glows* which occasionally light up the northern sky, are the effects of the Aurora, whilst its principal display is below the observer's view; possibly below the pole of the earth. Another remarkable circumstance is, that the grandest and most frequent displays of the Aurora Borealis, are on the *winter side* of the equinoxes: or from the autumnal to the vernal equinox. Moreover, these displays are generally during an early part of the night, and often commence on the *eastern* side of the northern meridian: and but very seldom if ever, on the *western* side. These circumstances seem to have some relation to the position of the sun, at the times of their occurrence, and to favour the idea of a *westerly* motion in the Aurora.

That heat disturbs the natural electrical equilibrium of bodies is well known; and from the universal maxim in physics, viz. that no two bodies can occupy the same place, at one time, there is much reason to suppose that, where heat prevails, the electric fluid must give way. I am not aware that we have any *direct* experimental fact in support of this view, but *indirectly* we have: for a conducting wire forming a connection with the two poles of a voltaic battery, will not transmit as much

electricity when hot as when cold. The fact which I discovered on Clapham Common, near London, is still more in point:* for although it be the reverse of that we are looking for as *directly* in corroboration of the supposition, we can easily understand that if electricity will drive heat before it, (into a corner as it were,) a prevailing intensity of heat will drive electricity from one part of a body to another part of it. Indeed, all our thermo-electric experiments are demonstrative of the fact.

Under this supposition then, the earth would continually be electro-polar; being negative where the sun's heat is most intense, with respect to the colder regions; where, in consequence of its redundancy, the fluid might spring up into the air, by the help of aqueous vapour, &c. and thus produce the Aurora: the *northern* when the sun is on the southern hemisphere, and the *southern* when he is on the northern hemisphere. This of course, is a mere opinion that I have formed out of the materials described in this paper.

* The fact here alluded to was developed by means of an extensive Voltaic battery, and showed that an electric current is capable of producing an intense heat by its repellent action on the calorific matter.

XIII.—*Description of an Aurora Borealis.* By William Sturgeon, Esq.

(Read November 2nd, 1847.)

On Sunday night last, the 24th October, we had another grand display of the Aurora Borealis, attended with peculiarities of a remarkable character, and such as are but seldom witnessed. The Aurora was first seen as early as a quarter before six in the evening; at which time, and during an hour afterwards, streamers of considerable magnitude and of different colours were seen to shoot upwards, from a low altitude in the heavens to the zenith of the observers. The grandest display of these streamers occurred about half-past six o'clock. They were of various hues—some crimson, some pink, others yellow, green, and violet. The largest of the whole appeared like an immense pillar of crimson light, situated about the north-west. The others were generally as-

sembled about the true north; the whole had a slow *lateral* motion from *east* to *west*, across the northern part of the meridian.

On Monday I went to Cantsfield, (about four miles south of Kirkby Lonsdale) where I heard of a still more extraordinary phenomenon than anything that was seen at Kirkby Lonsdale or Biggins. About ten o'clock on Sunday night, there appeared in the west, or rather a little south of the west point in the heavens, a fiery coloured light, which stretched, from a broad base at the horizon, to nearly the zenith. It soon became of a deeper red, approaching to crimson, and commenced a motion towards the north-east; and eventually, after being seen for about half an hour, it disappeared altogether in that quarter.

No cloud was present during the whole time, and the moon shone with her usual lustre in a clear sky.

Some splendid meteoric stars fell during the time of observation. Much distant lightning was seen during the evening, both at Cantsfield and at Kirkby Lonsdale.

I will here beg to remark, that large meteoric stars have been very frequent of late. Many of them have traversed a long arch of the heavens, and eventually have burst into a number of glowing balls, very much in the manner of sky rockets. Lightning also, has frequently been seen, in the evenings, within the present month.

Biggins, October 28th, 1847.

XIV.—*On the Formation of Clouds, as observed in the locality of Kirkby Lonsdale, Westmorland, in the month of October*, 1847. By William Sturgeon, Esq., in a letter to E. W. Binney, Esq.

(Read November 2nd, 1847.)

My Dear Sir,

Having had some experience as an observer of clouds, but having never witnessed such regular, and long continued transitions in the forms of aqueous vapour as those which have appeared, within the last fortnight, in this locality; nor being aware that any such have been recorded by Meteorologists, a description of them will be interesting to those philosophers whose studies are devoted to this class of natural phenomena.

The village in which I now reside, and where

these observations were made, is called Biggins, situated within a mile of Kirkby Lonsdale, and upon a mass of limestone rock, which rises steeply from the river Lune, which is about a mile distant from Biggins. Close to the river side the rock is covered with good soil, which grows excellent grass and corn ; but on the first steep rise of the acclivity, large blocks of limestone, in many places piled one above another, appear considerably higher than the soil, though a great portion of the space produces good pasturage, and is well stocked with fine trees, principally ash.

Opposite to Biggins, on the eastern side of the Lune, is Casterton Fell, which is one of a long chain of mountains that forms the eastern boundary of Lonsdale. The summit of Casterton Fell is about four miles from Biggins, with a well cultivated valley and the river Lune between them. The river and the chain of mountains are nearly parallel to each other, and to the meridian. The river runs southward to Lancaster, and empties itself into Morecambe Bay.

On the forenoon of Friday, the 1st instant, being in Kirkby Lonsdale, my attention was arrested by

a splendid bank of clouds rising from behind Casterton Fell, and extending both northwards and southwards, for several miles, along the eastern side of the mountain chain. The wind was easterly and pretty brisk, but still the clouds made no progress towards the place of observation. On looking about, I observed that the sky on the western side of Kirkby Lonsdale, and for a long track along the western side of the river, was completely covered with a dense rain-cloud ; but the space between this cloud and that bank of clouds which surmounted the fells, was perfectly clear : but the most curious part of the phenomena consisted in the stationary positions that both groups of cloud continued to appear in, when the wind was so high ; and not the trace of a cloud between them.

On my return to Biggins I had another *look out*, and still found the two groups of cloud nearly as before. I soon discovered the cause of their keeping their stationary positions in a high wind ; which was simply this.—The *western* border of the *eastern* clouds dissolved and disappeared as soon as it passed the summit of the mountains, whilst the *western* cloud, which hung over Biggins,

was recruited on its *eastern* edge, by a condensation of vapour from the clear part of the atmosphere. I watched this process for some hours, which was really beautiful. Nothing could be better calculated to give an idea of creation out of an apparent nonentity, than the continual formation of a dense cloud from the invisible vapour of a clear sky.

During the afternoon another phenomenon, of the same class, made its appearance. The *western* cloud, previously observed over this side of the river, had entirely disappeared; and one solitary insulated cloud hovered over head. The breeze still kept up, and this cloud kept its position. Its length might perhaps be a mile and a half, and its breadth three or four hundred yards. Having a pocket compass with me, I ascertained that its length was as nearly as possible in the magnetic meridian, almost at right angles to the direction of the wind. The phenomena displayed by this cloud were really interesting. It was dense in the middle, but ragged and thin at the edges. It was fed by the condensation of vapour on its *eastern* edge, and as continually wasted on its *western* edge by the re-dissolution or re-attenuation of that vapour. The axis of the cloud remained in nearly the same

position for more than three hours. It disappeared in the evening, by the whole heavens being overcast with dense cloud.

On the 14th October, I saw some fantastical transformations of clouds. They spring into existence in the clear air; float, in ever-changing shapes, for about a minute, then dissolve and disappear. They mostly commence as exceedingly thin filaments, which assemble in multitudes and form dense clouds. At this stage they often exhibit a whirling motion, spread out again into filamentaceous portions, and rapidly disappear.

As I have drawn no inference concerning the formation and annihilation of the clouds before described, I will take this opportunity of remarking that the phenomena would lead one to think that in the same horizontal stratum of air, the temperature is very different within a very short range of locality: and that there are vertical columns or strata, of different temperatures, arranged side by side alternately, over a small space of country.

On Casterton Fell, and over Biggins, &c. where the vapour formed cloud, the air must have been

colder than over the intervening valley, where no cloud was to be seen : and I cannot see any reason to think, that the vapour either ascended or decended during its transit over the valley. Descend it could not, because its specific gravity, whilst invisible, would not give it that tendency : and if it ascended it would reach a colder region of air, and still keep visible as cloud ; unless, indeed a column of warm air over the valley, reached from the ground to an altitude higher than the stratum of air in which cloud appeared. In that case there would not only be different degrees of temperature in the *same* stratum, but vertical columns of air of different temperatures also. Abiding by the facts only, it is obvious that the coolest air was over the highest land ; and consequently *nearer* to that land than to the valley below. But the general opinion amongst Meteorologists is, that the cold air found on mountains, is not due to the mountains themselves, but because their summits are situated in high strata of air, which would be cold whether the mountains were there or not. Perhaps it might be said that the superior radiation of heat from the valley, would warm the air to a higher altitude than that over the hills. Such an explanation would admit of a warm column between two cold ones ; but it would not explain the reason

of the *greatest portion* of the vacant space in which no cloud appeared, to be on the *east side* of the Lune, whilst a strong easterly breeze was blowing the *supposed* warm column of air, in the opposite direction. And in the case of the insulated cloud, which kept its stationary position for some hours, with a bright sky on every side, and the land westerly as high as at Biggins, the idea of radiation will not apply in any way.

If no satisfactory explanation has hitherto been given for phenomena of this class, the question will be an interesting one; and I should like to hear the opinions which such a problem might elicit from our Manchester Meteorologists.

I am, my dear Sir,

Yours very truly,

W. Sturgeon.

E. W. Binney, Esq.

XV.—*Description of an Aurora Borealis, seen at Biggins, near Kirkby Lonsdale, November 1st*, 1847. By William Sturgeon, Esq.

(Read December 7th, 1847.)

On Monday night, November 1st, I had a fine view of the Aurora Borealis, from this village. It consisted of an immense horizontal range, perhaps extending 140°, of streamers which shot their soft light slowly upwards, from a segment of fog, (it could hardly be called a cloud,) which was illuminated on its upper edge, and occasionally, in every part of it. The streamers were well defined, broad, but not lofty. The light of which they were composed was unusually soft and pleasing to the eye. Above the streamers, and sometimes amongst them, there appeared a crimson light, hovering in the sky. It had no appearance of being an *original* light, but looked more like the red component from a decomposition of the natural

white light. The stars were seen through it, though they were not so brilliant as during its absence. I have every reason to think that not only the various tints that are sometimes seen in the Aurora, but also some other of its characteristics, are the effects of refraction and reflection of the original auroral light; or in other words, that they are *secondary* effects.

XVI.—*Analysis of a Saline Spring in a Lead Mine, near Keswick.* By THOMAS RANSOME, Esq.

(Read November 2nd, 1847.)

THE water, of which the following is a description, is procured from a Lead Mine at Brandley, on the south-west side of Derwent Water, to the proprietor of which, Mr. Merryweather, of Keswick, I am indebted for the specimen of water, and also for the information about its immediate locality.

The entrance to the mine is several feet above the lake, and a level of two hundred yards in length is driven into the hill. At the extremity is the spring from which this water is taken; it rises through a small hole in the slate rock.

The water itself is quite clear, and has a saline

and disagreeable taste, and is often taken medicinally by the country people.

Its specific gravity is 1·016. The solid contents are the Chlorides of Calcium and Magnesium, Sulphate of Magnesia, and common Salt, which are in the proportion of three and two-fifths ounces to the imperial gallon.

They are contained in the following proportions in the imperial pint:

Chloride of Calcium	87·67	containing	55·54	Chlorine.
,, Magnesium...	1·53	......	1·12	......
,, Sodium	110·23	......	66·49	......
Sulphate of Magnesia ...	4·35	......	—	—
	203·78 grs.		123·15 grs.	
Chlorine, estimated as Chloride of Silver ...			123·10 grs.	

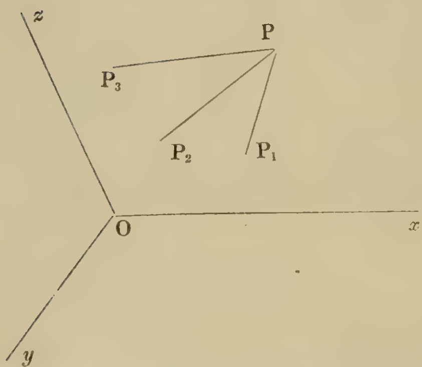
Or in 1000 parts by weight—

Chloride of Calcium	9·86
,, Magnesium	·17
,, Sodium	12·40
Sulphate of Magnesia	·48
Water	977·09
	1000·00

The peculiarity of this water is the large quantity of Chloride of Calcium which it contains. The largest amount recorded in any analysis I have been able to find, is in one of the saline springs at Leamington, which contains twenty-eight grains in the pint, or not quite one third of the quantity in the Brandley spring; but the deficiency of Sulphates of Magnesia and Soda will prevent it being used for the same purposes as those celebrated springs.

XVII.—*New Investigation of* LAPLACE'S *Theorem, in the Theory of Attractions.* POISSON'S *Remarks on this Theorem.* By ROBERT RAWSON, Esq.

(Read December 7th, 1847.)



LET each of any number of material points, P_1; P_2; P_3; &c. &c. attract a material point P with a force inversely as the squares of the distances PP_1; PP_2; &c. &c. The resultant of these forces in

amount and direction, when the boundary of the attracting points is any specified figure or surface, has been the great object of investigation by mathematicians since the theory of attractions was first developed by Newton, in his great work the Principia.

No subject of inquiry, since Newton's time, has been attended with greater difficulties, or received the attention of more profound and enlightened minds, than the theory of attractions. In pursuing the investigation, we are conducted to all the resources and refinements with which the domains of analysis have been enriched by the great geniuses of the last century, who have left upon immortal pages the deep impress of their great and noble intellects. Some of the most illustrious of these are Newton, James and John Bernoulli, to whom we are indebted for the useful and well known method of integration by parts, which Lagrange has successfully applied in order to establish his fine theory of the Calculus of Variations; Leibnitz, Euler, D'Alembert, Laplace, Lagrange, Poisson, Simpson, Mac-laurin,—and Ivory, who has the merit of being the first in this country who studied the works of the continental writers. All of these have en-

riched science with valuable artifices, modes of investigation, and results which they have obtained by means of successfully developing the artifices and new views which they have created.

To investigate the resultant of the forces P_1; P_2 &c. &c. which act upon the point P, it will be necessary in the first place, to refer all the points in the system to three planes $x \, O \, y$; $x \, O \, z$; $y \, O \, z$ at right angles to each other and arbitrarily fixed. We then resolve each force in the direction of these three fixed co-ordinate planes and sum the effects of the attractions in these directions, then these sums will enable us to calculate the resultant in magnitude and direction by the well known formula $R = \sqrt{A^2 + B^2 + C^2}$ and $\frac{A}{R} = \text{Cos.}\alpha$; $\frac{B}{R} = \text{Cos.}\beta$; $\frac{C}{R} = \text{Cos.}\gamma$; where R = The resultant and A, B, C the sum of the forces in the direction of the co-ordinate axes x, y, z respectively; and α, β, γ the angles which R makes with the co-ordinate planes. (See Poisson's Traité Mécanique, page 55.)

This mode of investigation was first laid down and pursued by the celebrated Maclaurin in his Treatise on Fluxions. See Mécanique Ana-

lytique, page 227, where Lagrange has enumerated the principal steps in the science of mechanics, and by whom they were made.

I may here state that besides the relations above given we have

$$\text{Cos.}^2\,\alpha + \text{Cos.}^2\,\beta + \text{Cos.}^2\,\gamma = 1$$
$$R = A\,\text{Cos.}\,\alpha + B\,\text{Cos.}\,\beta + C\,\text{Cos.}\,\gamma$$

Let x_1, y_1, z_1 be the rectangular co-ordinates of the point P_1, origin at O.

x_2, y_2, z_2 do. do. P_2 do.
&c. &c. &c.

And a, b, c be the rectangular co-ordinates of the point P

Put $P_1 P = w_1$ and $P_2 P = w_2$ &c. &c.

Let $\overset{x}{\Sigma}$; $\overset{y}{\Sigma}$; $\overset{z}{\Sigma}$ refer to all the material points situated in the lines parallel to axis x, y, z respectively, and each passing through the point P.

And let $\overset{x\,y}{\Sigma}$, $\overset{x\,z}{\Sigma}$, $\overset{y\,z}{\Sigma}$ refer to points placed in planes parallel to the co-ordinate planes xy, xz, yz respectively passing through the point P,

excepting those points situated in lines passing through P and parallel respectively to x, y, & z.

Σ refers to all the other points of the system.

Then we have $\frac{\rho}{w_1^2}$ = the attraction of P_1 on P in the direction of P_1P, where ρ is a constant and equal to P_1's amount of attraction at a unit of distance from P.

The cosines of the angles which P_1P makes with the axis of x, y, z respectively will be $\frac{a-x_1}{w_1}$, $\frac{b-y_1}{w_1}$; $\frac{c-z_1}{w_1}$ (See Poisson's Mécanique, p. 171.)

Hence, if we resolve $\frac{\rho}{w_1^2}$ parallel to the co-ordinate axis by multiplying it by the cosines of the angles which it makes with the co-ordinate planes we shall have—

$$\left.\begin{array}{llll} \Sigma\cdot\frac{\rho(a-x_1)}{w_1^3} = \text{force parallel to the axis of } x \\ \Sigma\cdot\frac{\rho(b-y_1)}{w_1^3} = \quad \text{do.} & \text{do.} & y \\ \Sigma\cdot\frac{\rho(c-z_1)}{w_1^3} = \quad \text{do.} & \text{do.} & z \end{array}\right\}(1)$$

These forces are derived entirely from the material points which are not placed in the planes parallel to the co-ordinate planes, and passing through P.

$$\left.\begin{array}{l}\overset{x}{\Sigma}\cdot\dfrac{\rho}{w_1^2} = \text{the force of all the material points} \\ \qquad\quad \text{parallel to} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; x \\ \overset{y}{\Sigma}\cdot\dfrac{\rho}{w_1^2} = \qquad \text{do.} \qquad\qquad \text{do.} \qquad\qquad y \\ \overset{z}{\Sigma}\cdot\dfrac{\rho}{w_1^2} = \qquad \text{do.} \qquad\qquad \text{do.} \qquad\qquad z \end{array}\right\}(2)$$

These are the forces derived from the material points placed in the lines parallel to the co-ordinate axes x, y, and z respectively.

$$\left.\begin{array}{l}\overset{x\,y}{\Sigma}\cdot\dfrac{\rho(a-x_1)}{w_1^3} = \text{the force parallel to } x\ldots\ldots\ldots\ldots \\ \overset{x\,y}{\Sigma}\cdot\dfrac{\rho(b-y_1)}{w_1^3} = \qquad \text{do.} \qquad \text{do.} \qquad y\ldots\ldots\ldots\ldots \end{array}\right\}(3)$$

The force parallel to z will be nothing from $\overset{x\,y}{\Sigma}\cdot$

$$\left.\begin{array}{l}\overset{x\,z}{\Sigma}\cdot\dfrac{\rho(a-x_1)}{w_1^3} = \text{force parallel to } x \;\ldots\ldots\ldots\ldots\ldots \\ \overset{x\,z}{\Sigma}\cdot\dfrac{\rho(c-z_1)}{w_1^3} = \qquad \text{do.} \qquad z \;\ldots\ldots\ldots\ldots\ldots \end{array}\right\}(4)$$

The force parallel to y will be nothing from $\overset{x\,y}{\Sigma}\cdot$

$$\left.\begin{aligned} &\overset{y\,z}{\Sigma}\cdot\frac{\rho(b-y_1)}{w_1^{\,3}} = \text{force parallel to } y \;\ldots\ldots\ldots\ldots\ldots \\ &\overset{y\,z}{\Sigma}\cdot\frac{\rho(c-z_1)}{w_1^{\,3}} = \qquad \text{do.} \qquad z \;\ldots\ldots\ldots\ldots\ldots \end{aligned}\right\}(5)$$

The force from $\overset{y\,z}{\Sigma}$ being nothing parallel to x.

Collecting the forces parallel to axes x, y, z respectively we shall have—

$$A = \Sigma\cdot\frac{\rho(a-x_1)}{w_1^{\,3}} + \overset{x\,y}{\Sigma}\cdot\frac{\rho(a-x_1)}{w_1^{\,3}} + \overset{x\,z}{\Sigma}\cdot\frac{\rho(a-x_1)}{w_1^{\,3}} + \overset{x}{\Sigma}\cdot\frac{\rho}{w_1^{\,2}}\ldots(6)$$

$$B = \Sigma\cdot\frac{\rho(b-y_1)}{w_1^{\,3}} + \overset{x\,y}{\Sigma}\cdot\frac{\rho(b-y_1)}{w_1^{\,3}} + \overset{y\,z}{\Sigma}\cdot\frac{\rho(b-y_1)}{w_1^{\,3}} + \overset{y}{\Sigma}\cdot\frac{\rho}{w_1^{\,2}}\ldots(7)$$

$$C = \Sigma\cdot\frac{\rho(c-z_1)}{w_1^{\,3}} + \overset{x\,z}{\Sigma}\cdot\frac{\rho(c-z_1)}{w_1^{\,3}} + \overset{y\,z}{\Sigma}\cdot\frac{\rho(c-z_1)}{w_1^{\,3}} + \overset{z}{\Sigma}\cdot\frac{\rho}{w_1^{\,2}}\ldots(8)$$

These are the forces which act parallel to the co-ordinate axes where the values of $\Sigma\cdot w_1$ &c. &c., in terms of the co-ordinates of the point attracted and the point attracting are as follows.

$$\left.\begin{array}{l}
\Sigma\cdot w_1 = \Sigma\cdot\left\{(a-x_1)^2+(b-y_1)^2+(c-z_1)\right\}^{\frac{1}{2}};\quad \overset{x\,y}{\Sigma}\cdot w_1 = \overset{x\,y}{\Sigma}\cdot\left\{(a-x_1)^2+(b-y_1)^2\right\}^{\frac{1}{2}} \\[2ex]
\overset{x\,z}{\Sigma}\cdot w_1 = \overset{x\,z}{\Sigma}\cdot\left\{(a-x_1)^2+(c-z_1)^2\right\}^{\frac{1}{2}};\quad \overset{y\,z}{\Sigma}\cdot w_1 = \overset{y\,z}{\Sigma}\cdot\left\{(b-y_1)^2+(c-z_1)^2\right\}^{\frac{1}{2}} \\[2ex]
\overset{x}{\Sigma}\cdot w_1 = \overset{x}{\Sigma}\cdot(a-x_1);\quad \overset{y}{\Sigma}\cdot w_1 = \overset{y}{\Sigma}\cdot(b-y_1)\ \ \&\ \ \overset{z}{\Sigma}\cdot w_1 = \overset{z}{\Sigma}\cdot(c-z_1)
\end{array}\right\}\ (9)$$

Let us now substitute the values of $\Sigma\cdot w_1$ &c. &c. as given in the system of equations (9), in the equations (6), (7), and (8), and we shall have—

$$\left.\begin{aligned}
\frac{\mathrm{A}}{\rho} &= \Sigma\cdot\frac{(a-x_1)}{\left\{(a-x_1)^2+(b-y_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}}+\overset{x\ y}{\Sigma}\cdot\frac{(a-x_1)}{\left\{(a-x_1)^2+(b-y_1)^2\right\}^{\frac{3}{2}}}+\overset{x\ z}{\Sigma}\cdot\frac{(a-x_1)}{\left\{(a-x_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}}+\overset{x}{\Sigma}\cdot\frac{1}{(a-x_1)^2} \\
\frac{\mathrm{B}}{\rho} &= \Sigma\cdot\frac{(b-y_1)}{\left\{(a-x_1)^2+(b-y_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}}+\overset{x\ y}{\Sigma}\cdot\frac{(b-y_1)}{\left\{(a-x_1)^2+(b-y_1)^2\right\}^{\frac{3}{2}}}+\overset{y\ z}{\Sigma}\cdot\frac{(b-y_1)}{\left\{(b-y_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}}+\overset{y}{\Sigma}\cdot\frac{1}{(b-y_1)^2} \\
\frac{\mathrm{C}}{\rho} &= \Sigma\cdot\frac{(c-z_1)}{\left\{(a-x_1)^2+(b-y_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}}+\overset{x\ z}{\Sigma}\cdot\frac{(c-z_1)}{\left\{(a-x_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}}+\overset{y\ z}{\Sigma}\cdot\frac{(c-z_1)}{\left\{(b-y_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}}+\overset{z}{\Sigma}\cdot\frac{1}{(c-z_1)^2}
\end{aligned}\right\}(10)$$

We must remember that the sum of the forces of the material particles which are on one side of the attracted point, with respect to the three planes passing through it and parallel to the co-ordinate planes, will be positive, and the sum of the forces

of the material particles on the other side will be negative, this will necessarily give rise, generally, to as many negative terms in the equations (10) as positive, in consequence of the material particle placed at P being acted upon by the difference between the forces on one side of it and those on the other.

If we follow the steps of Laplace, and put

$$\frac{V}{\rho} = \Sigma \cdot \frac{1}{\left\{(a-x_1)^2+(b-y_1)^2+(c-z_1)^2\right\}^{\frac{1}{2}}} + \overset{x\,y}{\Sigma} \cdot \frac{1}{\left\{(a-x_1)^2+(b-y_1)^2\right\}^{\frac{1}{2}}} + \overset{x\,z}{\Sigma} \cdot \frac{1}{\left\{(a-x_1)^2+(c-z_1)^2\right\}^{\frac{1}{2}}}$$

$$+ \overset{y\,z}{\Sigma} \cdot \frac{1}{\left\{(b-y_1)^2+(c-z_1)^2\right\}^{\frac{1}{2}}} + \overset{x}{\Sigma} \cdot \frac{1}{(a-x_1)} + \overset{y}{\Sigma} \cdot \frac{1}{(b-y_1)} + \overset{z}{\Sigma} \cdot \frac{1}{(c-z_1)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

Differentiate this equation with respect to a, b, &c. respectively, and we shall have—

$$\left.\begin{aligned}
-\frac{d\mathrm{V}}{\rho da}&=\Sigma\cdot\frac{(a-x_1)}{\left\{(a-x_1)^2+(b-y_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}}+\overset{x\ y}{\Sigma}\cdot\frac{(a-x_1)}{\left\{(a-x_1)^2+(b-y_1)^2\right\}^{\frac{3}{2}}}+\overset{x\ z}{\Sigma}\cdot\frac{(a-x_1)}{\left\{(a-x_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}}+\overset{x}{\Sigma}\cdot\frac{1}{(a-x_1)^2}\\
-\frac{d\mathrm{V}}{\rho db}&=\Sigma\cdot\frac{(b-y_1)}{\left\{(a-x_1)^2+(b-y_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}}+\overset{x\ y}{\Sigma}\cdot\frac{(b-y_1)}{\left\{(a-x_1)^2+(b-y_1)^2\right\}^{\frac{3}{2}}}+\overset{y\ z}{\Sigma}\cdot\frac{(b-y_1)}{\left\{(b-y_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}}+\overset{y}{\Sigma}\cdot\frac{1}{(b-y_1)^2}\\
-\frac{d\mathrm{V}}{\rho dc}&=\Sigma\cdot\frac{(c-z_1)}{\left\{(a-x_1)^2+(b-y_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}}+\overset{x\ z}{\Sigma}\cdot\frac{(c-z_1)}{\left\{(a-x_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}}+\overset{y\ z}{\Sigma}\cdot\frac{(c-z_1)}{\left\{(b-y_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}}+\overset{z}{\Sigma}\cdot\frac{1}{(c-z_1)^2}
\end{aligned}\right\}\quad(12)$$

Hence, by referring to the system of equations (10), we shall have the following equations obtained by Laplace by means of the above beautiful artifice of partial differentiation.

$$\frac{dV}{da} = -A; \quad \frac{dV}{db} = -B \;\&\; \frac{dV}{dc} = -C \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

If we differentiate equations (12) again with respect to a, b, c respectively, we shall have—

$$-\frac{d^2V}{\rho d a^2} = \Sigma \cdot \left\{(a-x_1)^2+(b-y_1)^2+(c-z_1)^2\right\}^{-\frac{3}{2}} - 3(a-x_1)^2\left\{(a-x_1)^2+(b-y_1)^2+(c-z_1)^2\right\}^{-\frac{5}{2}}$$

$$+\overset{x\ y}{\Sigma} \cdot \left\{(a-x_1)^2+(b-y_1)^2\right\}^{-\frac{3}{2}} - 3(a-x_1)^2\left\{(a-x_1)^2+(b-y_1)^2\right\}^{-\frac{5}{2}}$$

$$+\overset{x\ z}{\Sigma} \cdot \left\{(a-x_1)^2+(c-z_1)^2\right\}^{-\frac{3}{2}} - 3(a-x_1)^2\left\{(a-x_1)^2+(c-z_1)^2\right\}^{-\frac{5}{2}} - 2\overset{x}{\Sigma} \cdot \frac{1}{(a-x_1)^3}$$

$$\therefore -\frac{d^2V}{\rho d a^2} = \Sigma \cdot \frac{(b-y_1)^2+(c-z_1)^2-2(a-x_1)^2}{\left\{(a-x_1)^2+(b-y_1)^2+(c-z_1)^2\right\}^{\frac{5}{2}}} + \overset{x\ y}{\Sigma} \cdot \frac{(b-y_1)^2-2(a-x_1)^2}{\left\{(a-x_1)^2+(b-y_1)^2\right\}^{\frac{5}{2}}}$$

$$+\overset{x\ z}{\Sigma} \cdot \frac{(c-z_1)^2-2(a-x_1)^2}{\left\{(a-x_1)^2+(c-z_1)^2\right\}^{\frac{5}{2}}} - 2\overset{x}{\Sigma} \cdot \frac{1}{(a-x_1)^3} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

Similarly we shall obtain—

$$-\frac{d^2\text{V}}{\rho\,d\,b^2}=\Sigma\cdot\frac{(a-x_1)^2+(c-z_1)^2-2\,(b-y_1)^2}{\left\{(a-x_1)^2+(b-y_1)^2+(c-z_1)^2\right\}^{\frac{5}{2}}}+\overset{x\,y}{\Sigma}\cdot\frac{(a-x_1)^2-2\,(b-y_1)^2}{\left\{(a-x_1)^2+(b-y_1)^2\right\}^{\frac{5}{2}}}$$

$$+\overset{y\,z}{\Sigma}\cdot\frac{(c-z_1)^2-2\,(b-y_1)^2}{\left\{(b-y_1)^2+(c-z_1)^2\right\}^{\frac{5}{2}}}-2\overset{y}{\Sigma}\cdot\frac{1}{(b-y_1)^3}\;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

$$-\frac{d^2\text{V}}{\rho\,d\,c^2}=\Sigma\cdot\frac{(a-x_1)^2+(b-y_1)^2-2\,(c-z_1)^2}{\left\{(a-x_1)^2+(b-y_1)^2+(c-z_1)^2\right\}^{\frac{5}{2}}}+\overset{x\,z}{\Sigma}\cdot\frac{(a-x_1)^2-2\,(c-z_1)^2}{\left\{(a-x_1)^2+(c-z_1)^2\right\}^{\frac{5}{2}}}$$

$$+\overset{y\,z}{\Sigma}\cdot\frac{(b-y_1)^2-2\,(c-z_1)^3}{\left\{(b-y_1)^2+(c-z_1)^2\right\}^{\frac{5}{2}}}-2\overset{z}{\Sigma}\cdot\frac{1}{(c-z_1)^3}\;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$$

By adding equations (14), (15) and (16) together, we shall have—

$$\frac{d^2V}{\rho\, d a^2} + \frac{d^2V}{\rho\, d b^2} + \frac{d^2V}{\rho\, d c^2} = \overset{x\,y}{\Sigma}\cdot \frac{1}{\left\{(a-x_1)^2+(b-y_1)^2\right\}^{\frac{3}{2}}} + \overset{x\,z}{\Sigma}\cdot \frac{1}{\left\{(a-x_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}}$$

$$+ \overset{y\,z}{\Sigma}\cdot \frac{1}{\left\{(b-y_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}} + 2\overset{x}{\Sigma}\cdot \frac{1}{(a-x_1)^3} + 2\overset{y}{\Sigma}\cdot \frac{1}{(b-z_1)^3} + 2\overset{z}{\Sigma}\cdot \frac{1}{(c-z_1)^3} \cdots\cdots \quad (17)$$

If we suppose $\overset{X\,Y}{\Sigma}\cdot$, $\overset{X\,Z}{\Sigma}\cdot$ and $\overset{Y\,Z}{\Sigma}\cdot$ to refer to all the points in the planes X Y &c. &c. parallel to the co-ordinate planes, and passing through the material point P; we shall have—

$$\frac{V}{\rho} = \Sigma\cdot \frac{1}{\left\{(a-x_1)^2+(b-y_1)^2+(c-z_1)^2\right\}^{\frac{1}{2}}} + \overset{X\,Y}{\Sigma}\cdot \frac{1}{\left\{(a-x_1)^2+(b-y_1)^2\right\}^{\frac{1}{2}}} + \overset{X\,Z}{\Sigma}\cdot \frac{1}{\left\{(a-x_1)^2+(c-z_1)^2\right\}^{\frac{1}{2}}}$$

$$+ \overset{Y\,Z}{\Sigma}\cdot \frac{1}{\left\{(b-y_1)^2+(c-z_1)^2\right\}^{\frac{1}{2}}} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (18)$$

And equation (17) will become—

$$\frac{d^2V}{\rho da^2}+\frac{d^2V}{\rho db^2}+\frac{d^2V}{\rho dc^2}=\overset{\text{X Y}}{\Sigma}\cdot\frac{1}{\left\{(a-x_1)^2+(b-y_1)^2\right\}^{\frac{3}{2}}}$$

$$+\overset{\text{X Z}}{\Sigma}\cdot\frac{1}{\left\{(a-x_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}}+\overset{\text{Y Z}}{\Sigma}\cdot\frac{1}{\left\{(b-y_1)^2+(c-z_1)^2\right\}^{\frac{3}{2}}} \quad (19)$$

$\frac{V}{\rho}$ = sum of every point in the mass of the attracting body multiplied by the reciprocal of its distance from P.

If the point P which is attracted, be exterior to all the attracting points, and such that none of the attracting bodies are in the planes passing through P, and parallel to the co-ordinate planes. Then we shall have from (19).

$$\frac{d^2V}{d\,a^2}+\frac{d^2V}{d\,b^2}+\frac{d^2V}{d\,a^2}=0\ldots\ldots\ldots\ldots\ldots\ldots \quad (20)$$

This equation was first given by the justly celebrated mathematical philosopher Laplace, (See Pratt's Mechanical Philosophy, page 155,) and Poisson was the first to show that the theorem was not true when the attracted point P was surrounded by the attracting particles, and his

reasoning on this question, in order to make the equation continuous, I must confess, has always appeared to me to be difficult to comprehend. The mode Poisson has adopted, is to divide the attracting body into two parts, one of which is a sphere surrounding the attracted point, and the other of course is the remaining shell, for every material point of which shell he supposes Laplace's equation to be true, and he then calculates the effects of the sphere upon the point P. This mode of reasoning has conducted Poisson to the equation

$$\frac{d^2V}{d\,a^2} + \frac{d^2V}{d\,b^2} + \frac{d^2V}{d\,c^2} = -\,4\,\pi\,\rho^1 \ldots\ldots\ldots\ldots\ldots \quad (21)$$

which he states to be true when the attracted particle is a part of the attracting mass. I am however, as before stated, unable to see the force of Poisson's reasoning on this question, and certainly the conclusion to which he arrives is different from the result which I have obtained in equation (19) by means of a very different Analysis. The condition which must be complied with, in order that Laplace's equation may be true is, from equation (19), that the points attracting must not be situated in any one of the

three planes, passing through the point P attracted, parallel to the co-ordinate planes.

And if the attracted point P be a part of the attracting mass, then equation (19) will give the relation between the three partial differential co-efficients of V with respect to the co-ordinates of the attracted point. I state these conclusions with great diffidence and respect for the high authority of Poisson, whose results on this subject appear to me to be different from those which the foregoing investigation has enabled me to obtain; and I cannot refrain from thinking, in consequence of being unable to alter the above researches, that Poisson's correction of Laplace's equation when the attracted point is a part of the attracting mass is not strictly right. The error which I conceive Poisson has made is, in stating that the shell into which he divides the attracting body will satisfy Laplace's equation.

Thus suppose $V = V^1 + U$, where V^1 refers to the shell and U to the sphere which surrounds the attracted point.

$$\therefore \frac{d^2V}{da^2} = \frac{d^2V^1}{da^2} + \frac{d^2U}{da^2}$$

$$\& \frac{d^2V}{db^2} = \frac{d^2V^1}{db^2} + \frac{d^2U}{db^2}$$

$$\& \frac{d^2V}{dc^2} = \frac{d^2V^1}{dc^2} + \frac{d^2U}{dc^2}$$

$$\therefore \frac{d^2V}{da^2} + \frac{d^2V}{db^2} + \frac{d^2U}{dc^2} = \frac{d^2V^1}{da^2} + \frac{d^2V^1}{db^4} + \frac{d^2V^1}{dc^2} + \frac{d^2U}{da^2} + \frac{d^2U}{db^3} + \frac{d^2U}{dc^2}$$

Now Poisson supposes that

$$\frac{d^2V^1}{da^2} + \frac{d^2V^1}{da^2} + \frac{d^2V^1}{dc^2} = 0 \dots\dots\dots\dots\dots \quad (22)$$

$$\therefore \frac{d^2V}{da^2} + \frac{d^2V}{db^2} + \frac{d^2V}{dc^2} = \frac{d^2U}{da^2} + \frac{d^2U}{db^2} + \frac{d^2U}{dc^2} \dots \quad (23)$$

The equation (22) is not, I believe, correct; it is established by Poisson from the commutability of the independent operations of d, & $\int f(x,a)\, dx$ where the integral sign $\int$ refers to dx, and the differential sign d refers to a; this principle only obtains when the limits of integration with respect to x are independent of a.

$$\text{Thus, } \frac{dV}{da} = \frac{dV^1}{da} + \frac{dU}{da}$$

where $-\frac{dV^1}{da}$ is the force arising from the shell and $-\frac{dU}{da}$ the force arising from the sphere—

$$\frac{V}{\rho} = \iiint \frac{dx \, . \, dy \, . \, dz}{\left\{(a-x)^2+(b-y)^2+(c-z)^2\right\}^{\frac{1}{2}}}$$ where the rectangular co-ordinates x y & z refers to any point in the attracting mass—(See Poisson Traité Mécanique, Nos. 96 and 107)—and the limits of integration depends upon the equation of the surface of the attracting mass. Differentiate the above equation with respect to a then we shall have—

$$\frac{-dV}{\rho da} = \iiint \frac{(a-x)\, dx\, dy\, dz}{\left\{(a-x)^2+(b-y)^2+(c-z)^2\right\}^{\frac{3}{2}}}$$

consequently,

$$\frac{A}{\rho} = \iiint \frac{(a-x)\, dx\, dy\, dz}{\left\{(a-x)^2+(b-y)^2+(c-z)^2\right\}^{\frac{3}{2}}} \;\ldots\ldots\; (24)$$

Similarly we have

$$\frac{B}{\rho} = \iiint \frac{(b-y)\, dx\, dy\, dz}{\left\{(a-x)^2+(b-y)^2+(c-z)^2\right\}^{\frac{3}{2}}} \;\ldots\ldots\; (25)$$

$$\& \ \frac{C}{\rho} = \iiint \frac{(c-z)\,dx\,dy\,dz}{\left\{(a-x)^2+(b-y)^2+(c-z)^2\right\}^{\frac{3}{2}}} \ \ldots\ldots \ (26)$$

See Poisson's Mécanique, No. 96. The limits of these integrations in the case of the shell V^1 are functions of a, b, c, the co-ordinates of the attracted point. Hence the differential of A with respect to a cannot be performed, in the case of V^1, before the integration with respect to x, y, z. These reasons have induced me to believe that Poisson's correction of Laplace's theorem is wrong.

And for the limits of integration in the equations (24), (25), and (26) to be independent of the co-ordinates of P, which must be the case if Laplace's equation is true, we must have the following conditions—

$$\text{If, } f(x, y, z) = 0 \ \ldots\ldots\ldots\ldots\ldots\ldots \ (27)$$

be the equation to the surface of the attracting mass

$$\left.\begin{array}{l} \therefore\ f(a, y, z) = 0 \\ \&\ f(x, b, z) = 0 \\ \&\ f(x, y, c) = 0 \end{array}\right\} \ldots\ldots\ldots\ldots\ldots\ldots \ (28)$$

will be the equations to three plane sections of the attracting mass passing through P, the attracted point, and parallel to the co-ordinate planes yz, xz, xy respectively. If the first of equation (28) for instance, gives impossible values for y, when z takes any value whatever &c. with the second and third, then Laplace's equation is true, if to the contrary it is not necessarily true.

XVIII.—*A Glance at the Geology of Low Furness, Lancashire.* By E. W. Binney, Esq.

(Read December 28th, 1847.)

The country which is intended to be described in this paper is the peninsula lying between the mouths of the Leven and Duddon, bounded on the north by a line from Ireleth to Ulverstone, and on the south by Morcambe bay: it is known by the name of Low Furness. The southern part of the district consists of gentle slopes, and hills of moderate elevation, but as you proceed north the land attains a greater altitude. It is traversed by a series of valleys, running nearly north and south, parallel to the estuaries of the Leven and the Duddon.

The low land skirting Morecambe bay, nearly all the distance from Aldingham to Barrow Head, shows evident signs of encroachments of the sea on the land. Mr. West, in his Antiquities of

Furness, published in 1803, at p. 383, in speaking of Rampside, says, "that the sands, on the south side of this village, cover a stratum of blue clay, immediately below which lies a bed of peat moss, mixed in many places with decayed hazels, and nuts upon their branches.* Upon the sands, on both sides of the isle of Fouldrey, numerous roots of large trees are to be seen after high tides." At another place he says, "the roots of trees demonstrate that a part of these sands has been a forest; they confirm the conjecture of Camden, that the shore was once situated a great way farther to the west, or rather to the south-west, than it was two centuries ago, and that a great tract of land has been wasted by the sea." No reasonable doubt can exist, but that the form of the land now constituting Low Furness, is very different to what it was two thousand years ago.

The lower part of the country, whether on the coast or in the valleys, is much enveloped by a

* Some persons, who view every deposit of peat containing the remains of trees, met with near a beach, as evidence of a subsidence of the land, would term the above a submerged forest, but it is far more probable, that a change of the currents in Morecambe bay has cut away the land on the coast above described, than that the land itself has subsided.

thick covering of drift, which hides the underlying strata from view.

Generally speaking, the strata occupy three zones of elevation, the new red sandstone being the lowest, the mountain limestone the middle, and the silurian the highest.

It is proposed to consider the subject under the following heads, namely, the Drift, New Red Sandstone, Coal Measures? Carboniferous Limestone, and Silurian.

First, as to the Drift.—This deposit, which more or less covers the country from Morecambe bay to Lindal Moor, consists of two kinds, namely, Till, composed of a reddish or brownish yellow coloured clay, mingled with angular and rounded pebbles, and coarse sand and gravel. The former occupies the tops of the more elevated portions of land, and the low land on the south and east skirting Morecambe bay, whilst the latter skirts the sides of the valleys, and is found to compose the rounded knolls which bound the valleys. These knolls are well seen in the valley of Furness, between Barrow Head and the old abbey, and there reach from thirty to forty feet in thickness.

The colour of the Till over the greater part of the district is of a deep red, but as you approach the higher land near Lindal Moor, where the largest amount of iron is found, it becomes of a brownish yellow, so the red colour is most probably owing to the per oxide of iron removed from some of the deposits of iron ore in the higher land above Dalton, during the time of the rising of the land, and consequent recession of the waters, and not during the period of the formation of the Till.

In Mr. Allison's iron mine, an open working, at Cross Gates, on the road leading from Dalton to Kirkby Ireleth, the upper portion of the iron is seen at one part running up into the Till, in a ridge two or three feet high, and three feet broad—the Till is about eight feet in thickness, and is of a deep red colour, having a band of yellow in the middle.

On the high land, composed of upper silurian rocks, which divides the valley where the Newland Iron works are situated from the valley of the Duddon, there is scarcely any appearance of drift.

The gravel and sand composing the rounded hills in Low Furness, especially that in the interior of them, is generally untinged by the red colour so universally shown in the neighbouring surface soils.

New Red Sandstone.—The whole of this formation in all its English divisions of upper red marls, upper new red sandstone, lower red marls, magnesian limestone, and lower new red sandstone has not been met with in Low Furness. The only representatives of it yet found are the upper new red sandstone and the magnesian limestone. There is, however, a probability of the lower new red sandstone being found under the magnesian limestone when that stratum is perforated.

The upper new red sandstone occupies the low country, south of Bardsea, by Aldingham, Rampside to Barrow Head, and the district lying between the last named place and Dalton, and extending westwards to the mouth of the Duddon. Its exact range is very difficult to determine, owing to the thick covering of drift, but it is well exposed in the valley of Beckansgill, especially near to Furness Abbey, and in the railway

cutting near the Dalton Junction, and on the line north-west of Dalton.

In the quarry at Furness Abbey the stone is of a deep red, variegated by bands and patches of a light drab colour, and containing traces of black oxide of manganese in the horizontal joints. The total thickness of the rock is unproved, twelve or fifteen yards of it only being exposed, but the characters of the stone seem to indicate that the part of the rock seen is the higher portion, similar to the sandstones of Liverpool and Runcorn. Very distinct ripple marks are shown on the upper surfaces of the stone.

The range of the strata is from south-west to north-east, and the dip to the south-east at an angle of 8°.

In the vicinity of Dalton, the rock comes in contact with the carboniferous limestone. It thus appears to occupy the lower sides of two great faults, one of which running north-east to south-west has thrown down* the limestone south of

* The general opinion is, that when new red sandstone and carboniferous limestone are found in contact, the former de-

Bardsea, on towards Barrow Head, and the other from the neighbourhood of the last named place, running nearly north and north-westward, up to beyond Dalton, also occupied by the new red sandstone.

The quality of the rock, as a building stone, especially that found in the vicinity of Furness Abbey, is far superior to its general character for durability, as many of the stones of that venerable ruin, built about the year 1130, exhibit scarce any symptoms of decay. Some of the stone comprising the mouldings and ornamental parts of the building, no doubt bears evident marks of the ravages of time; but this was to have been expected, as scarcely any of our best sandstones used for building purposes, will endure the test of exposure for seven hundred years, in such exposed positions. The builders of our old religious houses, appear not only to have been

posit overlies a bed of the latter, which has been separated from it and thrown down. But it may be argued with equal probability, that the limestone under the sandstone is in its original position, while the limestone on which there is now no sandstone has been raised, the sides of the dislocation giving no such evidences of the fault being "up or down" as are seen in the smaller dislocations in the coal measures.

possessed of considerable knowledge in selecting durable stones, but they also well understood the advantage of placing such in their proper bedding, as they were originally deposited in the earth, and did not put them on their edges, as too many of our modern builders do.

The whole of the stone forming the abbey, with the exception of some few pieces of Purbeck limestone used in the internal decorations, is of upper new red sandstone, obtained from the neighbourhood of the abbey.

Magnesian Limestone.—In other communications I have described the magnesian limestones of Collyhurst, Monton, Bedford, and Atherton, the only places in this county where this deposit has, as yet to my knowledge, been met with. The stone in these localities was identified with the limestones of Durham, Yorkshire, Nottingham, and Derby, more by its fossil organic remains and position, than from its appearance or chemical composition. Indeed, no casual observer would have considered the limestones to be of the same age, for while the former was a softy, earthy stone, generally of a cream colour, mingled with patches of dark red,

and occurring in thin ribbon bands, parted by red marls, and quite unfit for building purposes; the latter was one of the best building stones in the kingdom, and as such has been selected for building the new houses of Parliament. The former also, although called magnesian, contains little, if any, of that earth in its composition.

Mr. Watson, Chemist, of Bolton, found in a specimen of the limestone from Bedford, as follows:

"Carbonate of Lime	56.5
Aluminous and Silicious Earths	38.5
Oxides of Iron and Manganese	2.5
Water	2.5
	100.0"*

The identity of the strata was alone first proved by the organic remains. In this instance the value of the discovery of the late Dr. Smith, justly termed the father of English Geology, in reading the age of strata by their fossil organic remains, was most thoroughly proved. Probably there has not been any greater example of its correctness and utility.

* No. 5, page 23 of the Quarterly Journal of Geology.

Although the magnesian limestone had been observed in all its true characters in the neighbourhood of St. Bees' Head and Whitehaven, I am not aware of any author having mentioned the deposit in Low Furness, with the exception of Professor Sedgwick, who, at page 22 of his Geology of the Lake district, Author's copy, says, "I have before stated, that the magnesian limestone rises from beneath the red marl and sandstone of St. Bees' Head. It is of considerable thickness, and is well exposed in quarries near the road leading from Whitehaven to St. Bees. To the south of the valley of St. Bees it degenerates into a thin magnesian conglomerate, at the base of the red sandstone, and afterwards for many miles further south, the limestone disappears altogether; but it re-appears in its characteristic form near the village of Stank, in Low Furness. It is generally of a yellowish brown colour, and of a rather earthy structure, and is often full of cells lined with pure carbonate of lime. In the part of England here described, I believe it contains no organic remains, but many such remains are found in the same rock, in its range through Yorkshire and Durham."

Shortly after the publication of Professor

Sedgwick's interesting memoir, the writer of this notice, in company with two friends, Messrs. Harkness and Talbot, went into Furness for the express purpose of examining the magnesian limestone at Stank, above described. But after being engaged a whole day in traversing the district around Urswick, Dalton, Stank, and Furness Abbey, and making numerous enquiries of the inhabitants, they gave up the search as hopeless. The relation of the mountain limestone of Urswick and Dalton, with the upper new red sandstone of Furness Abbey and Dalton was examined. They also saw the place in the Stank valley, where searches for coal had been made many years ago. Although within a quarter of a mile of the place where it is met with, they missed seeing the limestone, as none of the people in the neighbourhood could direct them to it.

Probably the best evidence of the difficulty of discovering the stone, is in the circumstance of the monks of Furness having overlooked it when building their splendid abbey. These people, from the works left behind them, appear to have possessed a most excellent knowledge of the value of building stones, certainly not

excelled by architects of modern times, and would, beyond doubt, have selected the limestone in preference to the sandstone, had they been aware of its occurrence so near the abbey.

The place where the limestone occurs is in Mr. Thomas Kendall's field, near Hole Beck, on the right hand side of the road, leading from Stank to Hole Beck. It agrees in every respect with the description previously given by Professor Sedgwick. The quarry in which it is found is at present of small extent. After four yards in thickness of Till, is a bed of red marl, of a few inches in thickness. Under this comes the limestone, which is exposed to the depth of about two yards, and is of a warm yellow colour, resembling the stone of North Anston, in the West Riding of the county of York.

The stone, like many of the beds in Yorkshire, contains cells, partly filled with crystals of carbonate of lime. These, from their shapes, appear like the internal portions of casts of bivalve and univalve shells, but with these exceptions, I discovered no trace of organic remains.

The range of the limestone is north-east and south-west, and the dip 18 to 20° to the south-east. This was the case at the north-east end of the quarry, but at the south-west end of it the dip appeared to be west south-west, at an angle of 13°. From the position of the nearest upper new red sandstone, and other strata in the vicinity, I am inclined to take the first named dip as the true one, and to suppose the latter as the result of a slip or some other accidental disturbance.

Independently of the great interest of this deposit as most probably indicating the vicinity of coal measures, the quality of the stone seems to promise a building stone of a fair character, for this part of England. At present little is known of the thickness of the bed, or the amount of covering which lies over it. Both these points want investigating, before a safe conclusion can be come to as to the stone being available for building purposes.

By the kindness of my friend, Mr. James Gibb, chemist, I am able to give the following analysis of a part of the upper portion of the Hole Beck stone, which lies covered by red clay :

Carbonic Acid	38.40
Silica	11.65
Magnesia	8.95
Oxide of Iron	9.45
Lime	29.80
Water	1.75
	100.00

In composition, the stone somewhat resembles the magnesian limestone of Mansfield, Nottinghamshire, alluded to by Professor Sedgwick, at page 85 of his paper, on the Geological Relations and Internal Structure of the Magnesian Limestone, Transactions of the Geological Society of London, Vol. 3, Second Series. The following is the analysis made by the Rev. J. Holme, of the Mansfield bed :

Lime	28.750
Magnesia	11.125
Carbonic Acid	34.750
Silica	20.250
Red Oxide of Iron and Alumina	3.375
Earthy Muriates of Soda, Lime, and Magnesia	0.250
Water and loss	1.500
	100.000

So the Hole Beck stone contains a much greater amount of iron than the Mansfield bed.

The patch of limestone above described, cannot at present be connected with any deposit either above or below it, the district is so enveloped with drift. Extensive borings require to be made before the country can be well known.

No trace of the lower new red sandstone has yet been seen in the neighbourhood.

COAL MEASURES ?—About one-fourth of a mile north of the limestone quarry last described, and a little above Stank, many years ago, two pits were sunk in attempts to search for coal. I have not been able to learn the result. On the outside of the old shafts, there are now lying black and brown shales, more resembling coal measures than any other deposits that I am acquainted with. In them, I found no remains of plants, but I met with scales of Holoptychius and Palæoniscus.

CARBONIFEROUS, OR GREAT SCAR LIMESTONE.—This is the most important rock of the district, from the fact of its containing the valuable iron

ores of Furness. As previously stated, it is bounded by the upper silurian rocks, running a little south of Ulverstone, to near Ireleth, on the north, and by the new red sandstone formation on the south and west.

The valleys in which the present watercourses flow, all run nearly north and south, and are generally on lines of dislocation of the limestone.

The rock above Bardsea is quarried for making lime for agricultural purposes. Its upper portion is for the most part of deep red colour, owing to the presence of red oxide of iron. The dip of it is there east of south. The rock shortly afterwards appears to have a more easterly dip, and is exposed all the way to Scales, where it seems to have been thrown down by one of those north and south faults before alluded to.

Just before you enter Scales, and after you have reached the fault last named, by the pond on the roadside, there is a bed of black shale and some fragments of hard dark blue limestone. In company with my friends, Messrs. Harkness and Talbot, I some years ago found in this bed a considerable variety of shells and corals, which

were in a beautiful state of preservation, having their outsides preserved, and not being mere casts, as is generally the case with the fossils met with in similar deposits.

The specimens obtained were corals of the genera Ratepora, Millepora, Turbinolia, &c. Trilobites, several univalves, and bivalves of the genera Spirifer, Pecten, &c.

From Scales the limestone extends to Stainton, and thence northwards to Dalton, where it comes in contact with the upper new red sandstone. On the south of Stainton the limestone extends to the hill above the valley in which Newton is situate, and probably ranges further south, bounding the east side of the valley as far as Stank.

In the old quarry above Newton, on the roadside leading to Stainton, the most southerly point that I have observed it, the dip of the limestone is 60° east of south, at an angle of 25°. Its colour is of a deep red, and the general impression amongst the people residing about there was, that it contained veins of iron ore.

The valley at Newton, below the quarry last

described, is full of drift, which extends all the way to the upper new red sandstone of Furness Abbey before described, so it is impossible to say what deposits adjoin the limestone on the west.

It is very difficult to lay down the southern boundary of the limestone, but it is generally given in the geological maps which have been published, in a line running from a little north of Aldingham, on the Leven, to near Stank. Its north-west range by Newton and Dalton, to the Duddon at Ireleth, is pretty well defined.

The most interesting points in the deposit are the mines of red oxide of iron which are contained in it. These have been worked for ages, probably as long as any in the island, and still continue unexhausted.

This ore is now used in most of the iron works of England and Scotland, for the purpose of mixing with the poorer ores of the coal measures.

It appears to lie in fissures and erosions in the limestone, which in general run from south-east to north-west; but these main lines of direction are sometimes united by cross fissures,

as is often the case with dislocations in the coal measures.

The iron mines occur in the limestone near the junction of that deposit, with the upper new red sandstone, but I have heard of none of them traversing the latter rock. Up to the present time they have chiefly been found in Lindal, Dalton, and Stainton, and their extent towards the east has not yet been thoroughly proved.

One of the richest deposits of iron, is situate on Lindal Moor, in the estates of the Duke of Buccleuch and Lord Muncaster, and by those noblemen let at royalty rents. It is partly an open work. The fissure or valley in the limestone, where the iron occurs, must be from forty to fifty yards in width, and runs in a direction from north-west to south-east. The dip of the rock is east north-east. On the north wall of the vein, the limestone is coated with kidney iron ore, but the bulk of the deposit is a red paste, called "Raddle," consisting of nearly pure hydrate of the per oxide of iron, in which are mingled numerous crystals of smoke-coloured quartz, and detached pieces of kidney ore. The limestone, composing the walls of the vein, is so

much saturated with silica, that it will scarcely effervesce when treated with hydrochloric acid.

The depth of the vein the overlookers of the mine did not agree upon, for one stated that he thought he had reached the bottom of it, and the other stated that the bottom had not yet been found. Both, however, agreed in stating, that iron ore had been proved in some mines to extend seventy yards in depth, without ascertaining its lowest limit.

Near to the last described mine is another open work, in a valley or fissure of limestone, known by the name of Whitrigg. In its direction, character, and other particulars, it so much resembles the one at Lindal Moor, that it will be unnecessary to give a further description.

The surface Till in this neighbourhood is of a dirty yellow colour, and not of the red colour so prevalent further south.

At Cross Gates, on the road leading from Dalton to Kirkby Ireleth, I observed a small open working, belonging to Mr. Alison, previously alluded to. In this work, probably thirty

yards of the iron deposit was exposed, and showed its relation to the two or three yards of Till which bounded its upper part. In one part the iron made a bend into the Till, and appeared as if it had been pushed upwards, or else, that the iron had been removed on both sides, thus leaving a ridge in the middle before the Till was deposited.

In many parts, doubtless, portions of the iron must have been washed away by the waters flowing southwards, when the land, after the formation of the Till, was raised, as the colour of that deposit in the south of Low Furness plainly shows. For had the iron been removed during the time of the formation of the Till, the lower parts of that deposit, would, in all probability, have been coloured red like the upper parts, and the Till at Lindal would have been coloured like the same deposit further south.

The beds of iron appear to have been formed after the deposition of the carboniferous limestone, and before the deposition of the upper new red sandstone. The limestone rock, in some instances, seems to have been only fissured, but in others eroded, or water-worn, before the introduction of

the iron. During the formation of the old red, as well as of the new red sandstone, a vast amount of per oxide of iron appears to have been mingled with the waters of the ancient ocean. But still the quantity in the iron mines of Low Furness, is such as to indicate a proximity to the source from whence it originated. It appears to have been thrown up by volcanic action, and then carried, by some means, into the valleys and fissures where it is now found. But whether the iron was injected into the places where it is now met with, through the fissures immediately below, or was first mingled with the waters of the sea, which then flowed through the fissures and caverns of limestone, and gradually filled them up with the metallic matter, held partly in solution, as Professor Sedgwick thinks, is difficult to determine. The neighbouring district towards the mouth of the Duddon and Black Coomb, show abundance of proofs of having been formerly much disturbed by volcanic agency.

The upper silurian rocks, which bound the carboniferous limestone, which are merely alluded to as a boundary line, appear to have been elevated before the deposition on their edges of the latter rock. They form the northern part of the dis-

trict glanced at in this communication, and run in a line from about Ireleth to the south of Ulverstone.

Conclusion.—In the foregoing remarks, the southern and western boundaries of the carboniferous limestone, and its relation to the new red sandstone were cursorily glanced at, as they were not well ascertained, owing to the covering of drift. This can only be done by judicious boring. The glimpses which have been obtained of the magnesian limestone of Hole Beck, and the black shales of Stank, give every indication of a coal field lying under the southern and western parts of Low Furness. However, the depth of this deposit from the surface, its position, and the thickness and quality of its beds, all remain to be yet ascertained.

There is every advantage that can well be wished for a desirable locality. The district is near the coast, close to most valuable deposits of lime and iron, and at a convenient distance from the manufacturing districts of Lancashire, and the port of Liverpool. These circumstances added to the fact of the magnesian limestone of Hole Beck being near, will probably induce the land-owners to investigate the district, by judicious boring, under able superintendence.

XIX.—*On the Deodorization of Manures.* By JAMES YOUNG, Esq.

(Read December 14th, 1847.)

THE present is a time when anything on the treatment of manures must be acceptable, whether for preserving the various refuse matters for agricultural purposes, or for preventing their decomposition in cesspools, and such places, previous to their removal from the town to the country.

Our great sanatory problem, the solution of which has occupied much attention, is the prevention of decomposition in organic accumulations in towns. This has been partially accomplished by various methods, but the expense in some cases, and the noxious products in others, have proved a barrier to the adoption of any general plan.

Any substance to be generally used for this

purpose must be cheap, and must not only have the power of preventing decomposition in the organic matter to which it is added, but must also be free from any noxious effects upon the land or vegetables to which this matter may be applied as manure.

Being engaged in the manufacture of chlorine on a large scale, it occurred to me that the chlorine of manganese, which results from that manufacture, might have all those qualifications. The refuse of the chlorine process is principally chloride of manganese, with a variable quantity of per chloride of iron, and is at present considered an useless product, one house throwing away thirty-six tons per day of this solution, of a specific gravity varying from 1.280 to 1.300.

Having made a number of experiments during the summer, I am satisfied that this solution has, in a high degree, the property of preventing decomposition in organic matter. Several cesspools, and other places which gave out the most putrid odour, having been almost instantaneously sweetened by its application, an effect heightened by a small quantity of free chlorine, which this liquor always contains.

I need scarcely describe to chemists the action of this salt, the principal effect being, that the chlorine combines with the ammonium of the sulphuret of ammonium, and the manganese combines with the sulphur, thus forming chloride of ammonium and sulphuret of manganese. The former is well known as a valuable manure, and the latter being in a floculent state, will readily supply sulphur or sulphates to vegetables. The salts of manganese and iron are peculiarly fitted for land, both being employed by nature in feeding plants, both being akin to earths, and not possessing acrid metallic properties.

As there are at present in this country not less than 150 tons of this solution produced daily, which is $5\frac{1}{2}$lbs. per annum for each individual, from the experiments I have made, I consider there is more than sufficient to deodorize all the cesspools in Great Britain.

I may add, that after considering the matter carefully, in the different points of view which would naturally occur to a practical person, I mentioned the matter to Dr. R. A. Smith, and Dr. Lyon Playfair, both of whom fully agreed in the views I had taken on the subject.

XX.—*On the progress of Sculpture to the time of Phidias, with Remarks on the charges against him.* By Edward Holme, M.D., F.L.S., &c.

(Read April 11th, 1848.)

COMMUNICATED BY DR. FLEMING.

The following Paper was originally read by the late Dr. Edward Holme, at a meeting of the society, on the 16th day of November, 1816, and appears to have been intended as the first of a series of Essays on Ancient Art. It was withdrawn from publication at the time, probably as incomplete, and is now printed from the rough Notes in the handwriting of Dr. Holme, for which the council are indebted to his executors, S. D. Darbishire, Joseph Ewart, and S. Kay, Jun., Esqrs., who discovered them amongst his papers. Though wanting the advantage which the final revision of its Author might have conferred, this Essay will, the council feel assured, be regarded with peculiar interest, as, independently of its

intrinsic merit, it forms almost the only literary relic of the late very learned and most accomplished president of this society.

The following sketch was formed out of the materials collected for an Introduction to an Essay on the Elgin Marbles. I state this fact in order to account for the absence of many particulars which might have been expected in the Life of an Artist; but which would pre-occupy the ground I intended to take in a future Essay. A disquisition like the one proposed, in order to be executed in a manner satisfactory either to my colleagues or myself, demands a greater portion of leisure, and a mind less engaged and engrossed than I can at present command.

Notwithstanding the confessed superiority of the Greeks in the imitative arts, statuary and painting were plants of late growth, and raised to perfection by slow degrees.

We are informed by Pausanias, that, in the early stages of Grecian history, the only representations of their various deities were shapeless

masses of stone of extraordinary magnitude; that at Pharœ, in Achaia, thirty of these blocks were stationed, each of which was distinguished by the name of some particular divinity; and that the inhabitants of Thespiæ in Bœotia, from the earliest period, prostrated themselves before an idol equally inartificial, as the visible representative of the god, Ερως. Other instances might be adduced from the same author, to prove that Juno, Diana, the graces, Hercules, and other deities were worshipped under portraitures equally rude.*

Besides these ruder monuments, squared blocks, pillars, and pyramids were employed as images of superior beings, before any attempt was made to represent them in the human form. The most ancient statues of Castor and Pollux, at Sparta, were styled Δοκανα, and consisted of two perpendicular pieces of timber, placed parallel to each other, and united at the extremities by two horizontal beams. This seems to have been the origin of our present symbol for the sign of Gemini in the zodiac, as it corresponds with the symbol usually employed to denote that constellation.†

* Anach. VI. 184.

† Holland's Plut. 174, 2 Callimach. Fragm. 105.

The statue of Minerva, at Lindus, in the island of Rhodes, was merely a simple column; seven pillars, representing the seven planets, stood by the road side between Sparta and Arcadia; and a single pillar at Corinth designated Minerva, the protectress of that city. As the arts advanced, the Greeks invented a variety of names to express what we translate by the single term "statue;" but the word Κιων, literally signifying a column, was retained, even to the latest period of their glory, to signify indifferently either a column or a statue. At Corinth, Jupiter μειλιχιος was represented by a pyramid, and a cone of white marble was the symbol under which Venus was adored at Paphos.*

The first approach towards an imitation of the human form was to place a head upon a squared shaft or pedestal, called by the Greeks ἑρμα; a further effort added hands and feet to the ἑρμα, but the former adhered closely to the sides, and the latter were not detached. The first Greek artist who outlined the eye and the ear, disengaged the arms from the side, and gave an air of motion to the feet, was Dædalus, who flourished

* Max. Tyr. VIII. c. 3. Tacitus Hist. II. 3.

about 650 years before the commencement of the christian era. His performances, as will be readily imagined, were extremely rude; and his name became a familiar expression in after ages for whatever was antiquated and barbarous in art.*

On the throne of Apollo, at Amyclæ, a most magnificent monument of art executed by Bathycles of Magnesia, the deity was represented by a bronze pillar, thirty cubits in height, to which was attached a head, with arms and feet. He was armed with a helmet for defence, and bore a bow and a spear in his hand. This figure was considered a relic of most remote antiquity, even in the time of Bathycles, and was obviously antecedent to the employment of those symbols, which were fixed upon by succeeding artists, as the distinguishing attributes of Apollo.

The most ancient production of art in bronze was an image of Jupiter, which stood in the temple of Minerva, at Sparta. This statue was not cast at a single jet; but each of the members was formed separately, and afterwards united by rivets. This extraordinary performance was

* Pausan. III. c. 19, p. 198.

ascribed to Learchus, of Rhegium, a pupil of Dipænus and Scyllis; or, according to other authorities, of Dædalus.*

Plastic modelling, or the art of forming figures in soft masses, was first practised by Rhæcus, who constructed the temple of Venus at Samos.† A single bronze statue by this artist was seen by Pausanias, in the temple of Diana at Ephesus, where it was called "Night."‡ A sitting figure within the Acropolis of Athens, was the production of Endæus, a pupil of Dædalus.|| The chest of Cypsalus a most interesting relic, carved out of cedar, and inlaid with ivory and gold, was a work of high antiquity. The cover and sides were enriched by a variety of figures in distinct groups.§ A marble statue of the Pancratiast Arrachion, which stood in the forum at Phigalia, was executed in the ancient style; the arms being braced close to the sides, and the feet hardly

* ἄγαλμα ἐκ χαλκȢ πέποιηται παλαίοτατον πάντων ὁπόσα ἔστι χαλκȢ. Pausan. III. c. 17, p. 194.

† Circa 700 A.C. Anachar. VII. 135.

‡ Pausan. c. 10, p. 686.

|| Pausan. c. 1, p. 26.

§ A very interesting attempt to explain this has been made by Professor Heyne, of Gottingen.

parted from each other.* Arrachion was twice victorious at the olympic games—viz. in the fifty-third and fifty-fourth Olympiad.

Sculpturing in marble was practised at a much earlier period than the art of casting statues in bronze; for if we may believe Pliny, it was accomplished by Malas as early as the first Olympiad, and was practised by his descendants in regular succession, for the space of 240 years. In the fiftieth Olympiad flourished Dipænus and Scyllis, natives of Crete, and pupils of Dædalus. Their works were chiefly executed in Parian marble; but various instances are on record, which prove that occasionally they employed ebony.

Of the oldest artists in bronze, it will be sufficient to mention a few only, who have achieved a more than common celebrity, or whose eras permit of being precisely determined. Ageladas of Argos, executed a bronze chariot, drawn by four horses, and containing two figures, representing Cleosthenes, who was victorious in the sixty-sixth Olympiad, and his charioteer. (ʹηνιοχος).

* ἀνδριας τα τε ἄλλα αρχαῖος. και ȣχ' ἥκιςα επι τῷ σχημαṫι. ȣ διεςασι μεν πολυν ὁι ποδες, καθηνται δε παρὰ πλευρα ἀἱ χειρες ἄχρι των γλȣτων. Paus. VIII. 40. p. 520.

Contemporary with Ageladas, were Olegias and Onatas, of Ægina. Diomenes, the son and successor of Hiero, of Syracuse, dedicated to Jupiter a chariot and two horses of bronze, the production of Onatas. He likewise cast many single figures and equestrian statues; amongst the former may be enumerated an Apollo, at Pergamos, which was admirable for its size and beauty; and the celebrated statue of Ceres, at Phigalia.

We may now proceed to that brilliant epoch which commences with the death of Cimon, at the close of the eighty-third Olympiad, an event which placed the whole fortunes of his country at the sole disposal of Pericles, and when the art of statuary was advanced almost to its meridian splendour by the talents of Phidias. A critical review of what information can be obtained respecting his productions is deferred, as I have previously stated, to a future opportunity, when the literary notices now collected will be applied to the elucidation of several disputed points concerning the marbles brought from Athens by Lord Elgin.

Phidias appears to have been a man gifted with

an extraordinary versatility of talents. According to Pliny, he originally studied the art of painting, but, with the exception of a portrait of Pericles, no productions of his pencil are remaining. His performances in marble, bronze, and ivory, were numerous, though it has been remarked that his execution was by no means rapid.* Among his earlier productions may be enumerated two statues of Venus, one of which was in Rome, in the time of Pliny, and the other in the temple of Venus Urania, at Athens. But the statue which would be viewed with most interest by his countrymen, was, unquestionably, his Nemesis. This statue was sculptured from that identical block of marble which was brought by the Persian invaders for the purpose of being formed into a trophy of their conquest, but which was, ultimately, converted into a testimonial of their defeat. It was stationed in a temple at Rhamnus, situated ten stadia from the field of Marathon. An epigram which appears in the Anthologia, has been thus translated by Hayley :—

> "Of ivory whiteness—from a mountain rock—
> A Median sculptor, in a massive block,

* *χρονȣ εδειτο, και σχολης πλειονος εις τα εργα.* Themistius VIII.

Shipped me for Attica,—and doom'd to stand
His mark of triumph o'er this Attic land.
But when at Marathon fall'n Persia groaned,
And for invasion shattered ships aton'd.
By Attic art, perfection's nurse, I rose
In form a goddess, who the proud o'erthrows.
In different characters my figure speaks,
To Persians, vengeance!—Victory to Greeks!"

He also executed, in bronze, a statue of Minerva, styled the "Beautiful." Although it may appear surprising to us, and contrary to all our received notions of good taste and propriety, his most celebrated productions were colossal statues of ivory, with drapery of gold. His statue of Venus in this style, which stood at Elis, was inferior to his Jupiter and Minerva. With regard to the order of time in which these works were executed, some remarks will be made in the sequel.

The statue of Jupiter, though sitting, was forty feet high. He wore a crown of olive leaves on his head, and held in his right hand an image of Victory, in his left a sceptre, formed of various metals, with exquisite skill, and surmounted by an eagle. The entire drapery of this statue, with the throne upon which it was placed, was

composed of pure gold, with a profusion of ornaments, both painted and in relief; and the latter was also inlaid with ivory, ebony, and gems. A particular description will be found in Pausanias, which is copied with fidelity in the travels of Anacharsis.

The statue of Minerva was undertaken by Phidias, at the express command of Pericles, in the eighty-third Olympiad, and was completed in the eighty-sixth. This statue was twenty-six cubits in height, equal, according to the tables given by the Abbe Barthelemy, to thirty-nine Parisian feet.

A short time after the completion of this statue, which was placed in the Parthenon, the talented artist fell a victim to political intrigue, and ended his life in prison, under imputations so injurious to his memory, that they demand a more particular investigation. I have purposely spoken of the disgrace and death of Phidias, in the most general terms, as a detail of all the circumstances attending them, requires a commentary like that of Bayle, and greatly exceeds the dimensions of our present sketch; nevertheless, the fate of an artist, who occupies so exalted a position in the annals of

sculpture, cannot be viewed with indifference, and it must prove highly agreeable to our moral feelings, to vindicate his character from those vile aspersions by which it has been blackened by tradition. The materials, both for his inculpation and defence, lie within a small compass, but are of very different complexions; and the dates, so essential to discussions of this nature, are remarkably defective. In one particular, and in that only, can the various narratives be said to harmonize—viz. that after the completion of his great work in the Acropolis, he was charged with embezzling a portion of the gold entrusted to him, for the drapery of the statue of Minerva—though it is asserted, that this accusation was a political manœuvre, not so much levelled against him, as intended to disgrace his patron.

In what follows, little consistency is apparent. The principal authorities are the Scholiast on Aristophanes, (page 604)—Diodorus Siculus, (XII. 39)—and Plutarch in his life of Pericles.

Diodorus, or rather the older historian Ephorus, whom he copies (as appears from a subsequent passage,) states that some of the artists associated with Phidias in the construction of the Parthenon,

were suborned by a band of conspirators against Pericles, to prefer this accusation against him. Plutarch, who derived his information from other sources, particularly mentions Menon by name, as one of the artists suborned, and as a willing instrument to destroy the reputation of a successful rival.

The trial was held in a public assembly, and Phidias was acquitted on the most satisfactory evidence; for the robe of Minerva, was, by a wise precaution, so constructed, as to allow of removal without injury either to itself or the statue.

The Biographer proceeds to relate, that Phidias had still to encounter the malice of his rivals, and to combat the perils attendant upon the eminent position, to which his matchless performances had elevated him. His offence now resolved itself into an act of profaneness. He was charged with introducing his own portrait and that of his patron, into the battle of Amazons, represented on the shield of Minerva. He was committed to prison where he died of disease; or more probably of poison, administered with the view of furthering and sustaining the impeachment of Pericles. The informer on this occasion, had his expenses paid

out of the public treasury, and was placed under the especial protection of the state.

It appears from this narrative, that Phidias died before his sentence was pronounced, otherwise he would have suffered the punishment of death, invariably inflicted upon all those convicted of the crime of sacrilege.

Another version of the narrative declares, that Phidias was condemned for embezzling the gold destined for the statue of Minerva, but this is probably only a repetition of the first charge, under a different form. As to the extent of his offence, in the absence of precise information, we are unable to form a satisfactory opinion. Suidas, indeed, tells us, that Pericles appropriated to his private use fifty talents of the sum provided for this purpose. This clumsy fabrication involves an absurdity, unless it is to be understood, that the amount was abstracted from the whole sum voted for the works in the Acropolis. The article, as it stands in Suidas, is so deplorably bad, that it is useless exposing its absurdity. Why should an additional support be sought for in conjecture, in a matter originating in so questionable a source; or reliance be placed upon an authority, in which

truth and fiction are so confounded, as almost to resist the test of criticism?

According to a still more extraordinary tradition, Phidias is represented as banished from Athens, and obtaining an asylum at Elis, where he executed the greatest of all his works,—the Olympian Jupiter. On this occasion, (Schol. Arist.) it is said that he again disgraced himself by yielding to his mercenary propensities, and perished by an ignominious death, the just reward of his perfidy. I am greatly mistaken, if, upon a close inspection of this passage, the whole story will not be found to be an idle fabrication, for by the laws of Athens, death, and not banishment, was the punishment annexed to the crime of sacrilege; and the testimony of the grammarian will cease to be a good authority, if it can be proved that the statue of the Olympian Jupiter was an earlier production than the Minerva in the Parthenon.

The trial of Phidias, the resolution of Pericles to strengthen his administration and increase his own security, by involving his country in war, and the Peloponnesian war thereby occasioned, form a series of events that are comprised in a

very short period of time. The Scholiast on Aristophanes, professes to copy Philocheres. The passage has been alleged to prove, that Phidias was tried during the archonship of Pythodorus, in Olympiad LXXXVII. 1. which was the first year of the Peloponnesian war. To this conclusion several objections can be raised. For instance, the building of the Propylæa was commenced in the archonship of Euthymenes, and completed in the space of five years. The Propylæa formed the entrance to the Acropolis, in which the Parthenon stood. Now Euthymenes was archon in Olympiad LXXXV. 4; the addition of five years to this date, brings us to the Olympiad LXXXVI. 4, at which period the Peloponnesian war commenced. The whole of the buildings were at that time complete, and an enquiry was, in all probability, instituted to ascertain how far the parties concerned had faithfully executed their contracts. To the enemies of Phidias this appeared to be a favourable opportunity of impeaching his integrity and effecting his ruin. On the other hand, it is highly improbable that Pericles would be anxious to commence, or to allow the means of completing the building of the Propylæa, when his political opponents had been successful in the impeach-

ment and condemnation of Phidias. Nay, the very passage in the text of Aristophanes, to which the scholiast refers, states, that the trial of Phidias occurred before the Peloponnesian war broke out; which corresponds with the narrative in Diodorus.

The date of the statue of Minerva, is capable of being more correctly determined. In the Chronicle of Eusebius, under Olympiad LXXXV. 2. it is stated "in this year Phidias completed his statue of Minerva." this was two years before the archonship of Euthymenes, and the commencement of the Propylæa. The Parthenon and the statue were finished at that time, but the articles of accusation against Phidias were not framed until the building of the Propylæa was completed.

From these premises the following inferences may be drawn. In the Olympiad LXXXIII. the splendid designs of Pericles, for the embellishment of the city were commenced, and the execution of the statue of Minerva, was assigned to Phidias. Ten years were employed in the completion of this great work, which was finished in the Olympiad LXXXV. 2. In the Olympiad LXXXV. 4. the Propylæa was commenced; and finished

LXXXVI. 4. In the following year the Peloponnesian war broke out, and before this the trial of Phidias took place.

What follows in the Scholium concerning the flight of Phidias to Elis, and his there being put to death is extremely improbable. Admitting that he had been found guilty, and suffered capital punishment; is it credible that the inhabitants of Elis, would suffer his name to remain on the statue of Jupiter, or assign a pension to his descendants? Is it reconcileable with the respect shown to his memory by keeping that statue in repair—in guarding the building in which he worked from dilapidation; and with the pride they experienced in pointing out to strangers the work-room of the artist? Leaving out of the question, then, the supposition of his ignominious death, is the remainder of the narrative regarding his flight to Elis, and his execution of the statue of Jupiter, entitled to more credit? The breaking out of the Peloponnesian war, which involved the inhabitants of Elis in the common cause, appears to be a most inauspicious period for the execution of so costly and laborious an undertaking. Yet a very ingenious and plausible argument has been advanced, in order to show that

this statue could not have been produced before the eighty-sixth or eighty-seventh Olympiad. One of the figures sculptured on the basis of the throne on which Jupiter sat, was supposed to bear a striking resemblance to Pantarcas, a young man who was greatly admired by Phidias. He was represented in the act of binding round his head the diadem, usually worn by a victor in the public games. Now Pantarcas, according to Pausanias, obtained a prize in the eighty-sixth Olympiad. Hence Corsini infers that the diadem has a reference to this victory, and that the entire statue was executed in the eighty-sixth Olympiad. The only passage, as far as I can discover, which affords an indication where the solution of this difficulty can be found, occurs in Pausanias, who says, "that the temple at Olympia, and the statue of Jupiter, were erected in honour of that deity out of the spoils taken in war, from the natives of Pisa and its vicinity, by the citizens of Elis, who wasted their country, and reduced them to obedience."*

* To those who depend upon the authenticity of all the scandalous chronicles of antiquity, it would be useless to point out the insufficiency of a conclusion deduced from a real or imaginary resemblance, in a case like this.

For an account of these petty wars it would be in vain to search the pages of general History. Pausanias describes a war equally favourable to the inhabitants of Elis; but this happened about the forty-eighth Olympiad. The Pisans, however, must have recovered from these and other losses, for we find in Strabo, that before the final ruin of the Messenians, the Pisans had joined them as allies. The war was carried on against the Messenians by the Lacedæmonians, who, on this occasion, were assisted by the Elians; and by the aid of so powerful an alliance, an end was put to what is called the third Messenian war. Pisa was taken, plundered, and so completely destroyed, that not a vestige, and scarcely the name, remained. This event occurred in Olympiad LXXXI. 1; which may therefore be considered the epocha of the foundation of the temple, and allows eight years for the labour bestowed on the statue.

It may not be inappropriate to offer a few remarks concerning the structure of ivory statues. It may be conjectured that these colossal figures were formed of plates or cubes applied to a nucleus, which was afterwards either wholly or in part, withdrawn, and united by cement. A

sculptor of Messene is stated to have skilfully restored the statue of Jupiter, at Olympia, after the pieces of which it was composed began to warp and discover their joints. Among other prodigies related to have happened on the assassination of the emperor Caligula, Suetonius says, "Olympiæ simulachrum Jovis, quod dissolvi transferrique Romam placuerat, edidit cachinnum."

Thus Hermes in Lucian, tells Jupiter that his most splendid statues which were made of ivory, only glitter on their outside with gold, but are hollow within; and offer accommodation to a whole senate of mice.

Various expedients, it appears, were resorted to, in order to defend statues of this description from the injuries to which they were exposed by variations of temperature, or changes in the atmosphere both as to dryness or moisture. Thus Pliny records that an ivory statue of Saturn, at Rome, was filled with oil (VII. 53, 54).

Another remarkable passage occurs in Pausanias, v. II. p. 108. He informs us that the statue of Jupiter, in the temple of Jupiter Olympius,

was placed upon a pavement of black marble, surrounded by a raised margin of Parian stone, to confine the oil which was intended to preserve the statue from the injurious effects of the exhalations which arose from the soil; for the temple is situated in a country abounding in marshes. On the other hand, he adds, the Acropolis at Athens being considerably elevated above the surrounding country, the air is deficient in moisture; it is, therefore, expedient frequently to sprinkle the floor of the temple with water, in order to preserve the statue of Minerva. At Epidaurus, again, the throne of the statue was placed over a well, as he was informed by the priests, to whom the care of the statue was entrusted. In spite, however, of these precautions, statues formed of so perishable a material as ivory, required frequent repair; and the author I have just quoted, states, that "the statue of Jupiter, at Olympia was restored by Damophon, who lived within a few years of Phidias. He re-united the separate pieces of which it was composed by cement, after they had warped and left considerable fissures."

It was also necessary, from time to time, to remove the stains on the surface of the ivory, an

office at Olympia, from respect to the statuary, conferred on the descendants of Phidias, with an ample salary annexed to it.

But "Claudite jam rivos."—

In the words of an eminent critic, I may conclude—"Nescio, Benevoli auditores, an vestram patientiam his nugis fatigaverim, meam certè eas scribendo fatigavi."

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INDEX TO THE PLATES.

The small numbers exhibit the greatest diameter of each object, in fractional parts of an inch. It was not found practical to represent them all on one scale.

OBJECTS FROM THE LEVANT MUD.

FIGURE.

1. Denticella tridentata—Ehr.

2. Biddulphia pulchella.

3. Amphitetras autidiluviana var. ?

4, 6, 8. Grammatophora Africana—Ehr.

5. ——————————var. ?

7, 9. ———— tæniæformis.

10. ? One of the Diatomaceæ.—Genus undetermined.

11. Striatella arcuata var. I have recently received this variety from Rhodes' Island, U.S. through Dr. Bailey.

12. Fragillaria.

13, 14. Gomphonema—two species.

15 to 20. Naviculæ.

21. This is called a Navicula in the text. I believe it to be a Synhedra. The central dot should be removed from the drawing, and the extremities made more square.

22. Surirella.

23, 24. Cocconeis—two species.

25. Cocconema.

26. Campylodiscus.

27. Rosalina globularis,—probably the Rotalia stigma Ehr. Viewed as a transparent object, and hence representing a section of the animal.

28. The same species in an advanced stage of growth—transparent.

29. The decalcified animal of the same.

30. Polystomella—transparent.

31, 32. Peneroplis—transparent.

33. Textillaria—transparent.

34. A Foraminifer: genus uncertain—transparent.

35. Inferior surface of Truncatulina tuberculata, as an opaque object.

36, 37. Spiroloculina—transparent.

38.*a* Biloculina: front view—opaque.

38.*b* ———— lateral view—transparent.

39. Lagena (Lagenula auctorum) transparent.

40, 41. Spicula of Sponge—probably of Tetheia. This and all the subsequent forms are represented as opaque objects.

42. Globular cortical balls of Geodia.

43. Radiating spiculum of the same.

44. Spiculum of some unknown sponge.

45. Calcareous spiculum.

46, 47. Siliceous spicula of Halichondrium.

48. Muricated sponge spiculum.

49. Calcareous spiculum—probably of one of the Eolidæ.

50, 51, 52. Rudimentary plates of Echinodermata.

53. Cribriform fragment of a matured Echinoderm.

54. Lamina of Pinna.

55. Portion of a detached prism of the same.

OBJECTS FROM THE CHALK—OPAQUE.

56. Rotalia, upper surface—Charing.

57. Ditto, lower surface—Charing.

58. Robulina or Cristellaria, oral orifice not distinct—Charing.

59. ? Charing.

60. Rotalia globulosa Ehr. Discorbis Lyell's Elements, p. 55 —Charing.

61. Textillaria globulosa Ehr.—Charing.

62. Textillaria—Charing.

63. Verneueilina? Charing.

64. Lateral aspect of some genus allied to Textillaria—Charing.

65. Base of the same—Charing.

66. Marginulina—Charing.

67. Cristellaria—Charing.

68. Ditto? Charing.

69, 70. Dentalina: two species—Charing.

71. Lagena or Oolina—Charing.

72. Section of Fig. 70—Charing.

73, 74. Apparently terminal cells of Dentalina aculeata, D'Orbigny—Charing.

75. Lateral view of Cytherina echinulata nobis.*—Charing.

76. Dorsal aspect of the same—Charing.

77. Cytherina concentrica nobis—a distinct species, exhibiting numerous concentric lines on its lateral aspect —Charing.

78. ——— umbonata nobis—Charing.

79. ——— serrata nobis—may be young of Fig. 75—Charing.

80. ——— lævis nobis—Charing.

81. Portion of a sponge spiculum? Charing.

82. Calcareous sponge spiculum. Chalk from a hollow flint.

83. Siliceous sponge spiculum. Ditto.

84. Lamina of shell structure—Charing.

85, 86. Detached prisms of the same—Charing.

* Mr. Harris has kindly permitted me to append these provisional specific names to the Entomostraca from Charing.

It is proper to observe, that all the microscopic observations detailed in the preceding pages, have been made with the beautiful and accurate instruments manufactured by our fellow-townsman Mr. Dancer, of Cross Street.

It was only whilst this concluding sheet was passing through the press, that I saw a short paper, by John Phillips, Esq., "On the Remains of Microscopic Animals in the Rocks of Yorkshire," published in the "Reports of the Proceedings of the Geological and Polytechnic Society of the West Riding of Yorkshire, for 1844-45." It confirms the statement of the existence of numerous Foraminifera in the Oolitic and Mountain Limestones. Dr. Carpenter also informs me, that he has seen one specimen of Oolitic limestone in which every oolitic granule contained a Foraminifer. Dr. Carpenter has been equally unsuccessful with myself in his search after Foraminifera amongst Mr. Darwin's South American specimens.

ERRATA.

Page 1, line 3—for *tridens*, read *tridentata*.
,, 19, line 29—for *frustules being*, read *frustules not being*.
,, 35, footnote—for *Endosolenia*, read *Entosolenia*.
,, 31, line 9—for *Orbicula*, read *nitida*.
,, 43, line 12—for 28 read 27.
,, 51, last line—for 23, read 26.
,, 57, footnote—for *Endosolenia*, read *Entosolenia*.
,, 58, Ditto, Ditto Ditto.
Plate 2—for *Fig.* 23, read 26.

LIST OF BOOKS, &c.

PRESENTED TO THE SOCIETY SINCE 1846.

DONORS.	
British Association for the Advancement of Science.	Report of the 15th Meeting of the Association.
Society of Antiquaries.	Archæologia, vol. XXXI.
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William Alexander Mackinnon, Esq.	History of Civilization, 2 vols., by Mr. Mackinnon.
Philosophical and Literary Society of Leeds.	Report of the Philosophical and Literary Society of Leeds, for 1844–45.
Zoological Society.	Various Numbers of Proceedings of the Zoological Society of London, and Reports of the Council and Auditors.
The Editor.	Nos. 1 and 2 of the British and Foreign Scientific Magazine.
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,, ,, ,,	A Number of the Quarterly Journal of the Geological Society.
,, ,, ,,	A Paper on the Scandinavian Drift, by Sir R. I. Murchison.
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W. B. Bayley, Esq.	A Memoir of Henry Vincent Bayley, D.D., by Mr. Bayley.
Philosophical and Literary Society of Leeds.	The Annual Report.
Lieut. M. F. Maury, A.M.	Astronomical Observations at the United States Naval Observatory, Washington, vol. I.
Société de Physique et d' Histoire Naturelle de Geneve.	Mémoires de la Societe de Physique et d' Histoire Naturelle de Geneve.
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London Institution.	Catalogue of the Library of the Institution, vol. III.
,, ,, ,,	Groves' Lectures on Physics.
Sir H. T. De la Beche, V.P.R.S., P.G.S., &c.	Memoirs of the Geological Survey of Great Britain, and of the Museum of Economic Geology, vol I.
J. C. Adams, Esq., M.A., &c.	An Explanation of the observed Irregularities in the motion of Uranus, by Mr. Adams.
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British Association for the Advancement of Science.	Report, for the year 1846.
James Black, M.D., F.G.S.	An Eclectic View of the Coal Formation, by Dr. Black.
Luke Howard, Esq., F.R.S.	Barometrographia for 1815, 16, 17, & 18, by Mr. Howard.
His Grace the Duke of Northumberland, F.R.S., and Sir J. F. W. Herschel, Bart., F.R.S., &c.	Results of the Astronomical Observations at the Cape of Good Hope, by Sir J. F. W. Herschel.

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The Royal Irish Academy.	Proceedings of the Academy for 1844, 1845, and 1846.
,, ,, ,,	Transactions of the Academy Vol. XXI. Part 1.
Royal Society.	The Philosophical Transactions of the Royal Society for 1847. Part 1.
,, ,, ,,	The Proceedings of the Royal Society, No. 67.
Royal Society of Edinburgh.	Transactions of the Royal Society of Edinburgh. Vol. XVI., part 3, and vol. XVII., part 2.
,, ,, ,,	Proceedings of the same Society, Nos. 29 and 30, for 1846–47.
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AN

ALPHABETICAL LIST

OF THE

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OF THE

LITERARY AND PHILOSOPHICAL SOCIETY OF MANCHESTER.

MARCH, 1848.

	Date of Election.
James Ainsworth	January 25th, 1805
Ralph F. Ainsworth, M.D.	April 30th, 1839
Thomas Ashton, M.D.	October 29th, 1824
Thomas Ashton	August 11th, 1837
John Atkinson	January 27th, 1846
Richard Parr Bamber	October 19th, 1821
Henry Bannerman	April 30th, 1824
Robert Barbour	January 23rd, 1824
James Barratt, jun	January 24th, 1834
Joseph Barratt	April 19th, 1842
John Frederic Bateman, M. Inst. C.E.	Jan. 21st, 1840
Thomas Bazley	January 26th, 1847
Charles Bell, M.D	January 25th, 1848
William Bell	January 26th, 1847
James Bevan	January 23rd, 1844
Edward William Binney	January 25th, 1842
Alfred Binyon	January 26th, 1838

	Date of Election.
Richard Birley	April 18th, 1834
James Black, M.D., F.G.S.	April 30th, 1839
John Blackwall, F.L.S	January 26th, 1821
Henry Bowman	October 29th, 1839
Edward Brooke	April 30th, 1824
W. C. Brooks, M.A.	January 23rd, 1844
Henry Browne, M.B	January 27th, 1846
Laurence Buchan	November 1st, 1810
John Burd, jun.	January 27th, 1846
Henry Cadogan Campbell	January 23rd, 1835
Frederick Crace Calvert	January 26th, 1847
John Young Caw	April 15th, 1841
Henry Charlewood	January 24th, 1832
David Christie	October 19th, 1847
Peter Clare, F.R.A.S.	April 27th, 1810
Charles Clay, M.D	April 15th, 1841
Richard Cobden, M.P.	April 29th, 1836
Thomas Cooke, jun	April 12th, 1838
Samuel Elsworth Cottam, F.R.A.S.	October 20th, 1837
James Crossley	January 22nd, 1839
Joseph S. Crowther	January 25th, 1848
Charles Cumber	November 1st, 1833
Matthew Curtis	April 18th, 1843
John Benjamin Dancer	April 19th, 1842
Samuel Dukenfield Darbishire	January 25th, 1822
John Davies, M.W.S.	November 1st, 1816
James Joseph Dean	November 15th, 1842
Joseph Cheeseborough Dyer	April 24th, 1818

Date of Election.

The Right Hon. the Earl of Ellesmere,
F.G.S. ....April 15th, 1841
Edwards Ethelston ....April 28th, 1840

William Fairbairn, M. Inst. C.E......October 29th, 1824
Pearson B. Ferguson.....................January 25th, 1848
Octavius Allen Ferris.....................January 26th, 1847
David Gibson Fleming ....January 25th, 1842
William Fleming, M.D......................April 18th, 1828
Richard Flint ....October 31st, 1818
James William Fraser ....January 22nd, 1839

Rev. William Gaskell, M.A.............January 21st, 1840
Samuel Giles ....April 20th, 1836
Thomas Glover ....January 21st, 1831
John Goodman ....January 25th, 1842
John Gould ....April 20th, 1847
John Graham ....August 11th, 1837
Robert Hyde Greg, F.G.S. ....January 24th, 1817
William Rathbone Greg....................April 26th, 1833
John Edgar Gregan ....January 25th, 1848
John Clowes Grundy......................January 25th, 1848

Edward Hacking ....January 27th, 1846
Rev. Robert Halley, D.D...................April 29th, 1845
Richard Hampson ....January 23rd, 1844
Robert Hardy, M.D ....January 27th, 1837
John Hawkshaw, F.G.S.& M. Inst. C.E., Jan. 22nd, 1839
William Charles Henry, M.D., F.R.S....Oct. 31st, 1828
Sir Benjamin Heywood, Bart., F.R.S. ...Jan. 27th, 1815

Date of Election.

James Heywood, M.P., F.R.S., & G.S. April 26th, 1833
James Higgins..................................April 29th, 1845
John Hobson ....January 22nd, 1839
Eaton Hodgkinson, F.R.S., M.R.I.A.,
F.G.S., &c...........................January 21st, 1820
James Platt Holden ....January 27th, 1846
Philip Henry Holland ....April 20th, 1847
Thomas Hopkins ....January 18th, 1823
Henry Houldsworth ....January 23rd, 1824
Richard Baron Howard, M.D..........January 25th, 1842

Paul Moon James ....January 27th, 1837
John Jesse, F.R.S., R.A.S., & L.S...January 24th, 1823
Rev. Henry Halford Jones..................April 21st, 1846
Joseph Jordan..............................October 19th, 1821
James Prescott Joule, Cor. Mem. of the
Royal Academy of Sciences, Turin, &c. Jan. 25th, 1842
William Joynson...........................January 27th, 1846

Alexander Kay ....October 30th, 1818
Samuel Kay ....November 1st, 1799
Samuel Kay, jun..........................January 24th, 1843
John Kennedy..................................April 29th, 1803

Henry Charles Lacy, M.P...............January 29th, 1827
Richard Lane ....April 26th, 1822
William Langton...............................April 30th, 1830
James Lillie..................................October 29th, 1830
John Rowson Lingard ....January 26th, 1847
Thomas Littler ....January 27th, 1825

Name	*Date of Election.*
John Lockett	January 25th, 1842
Joseph Lockett	October 29th, 1839
Benjamin Love	April 19th, 1842
James M'Connel	October 30th, 1829
William M'Connel	April 17th, 1838
Alexander McDougal	April 30th, 1844
John Macfarlane	January 24th, 1823
Edward William Makinson, B.A.	October 20th, 1846
William Makinson	January 24th, 1823
Robert Mann	January 22nd, 1839
Robert Manners Mann	January 27th, 1846
James Meadows	April 30th, 1830
Thomas Mellor	January 25th, 1842
William Mellor	January 27th, 1837
John Moore, F.L.S.	January 27th, 1815
L. A. J. Mordacque	October 29th, 1830
George Murray	January 27th, 1815
Alfred Neild	January 25th, 1848
William Neild	April 26th, 1822
Henry Newbery	April 30th, 1839
John Ashton Nicholls	January 21st, 1845
William Nicholson	January 26th, 1827
Geo. Wareing Ormerod, M.A., F.G.S.	Jan. 26th, 1841
Henry Mere Ormerod	April 30th, 1844
John Owen	April 30th, 1839
George Parr	April 30th, 1844

Date of Election.

John Parry ....April 26th, 1833
George Clarke Pauling ....January 25th, 1842
George Peel, M. Inst. C.E. ....April 15th, 1841
Peter Pincoffs, M.D......................January 25th, 1848
Archibald Prentice.......................January 22nd, 1819

Joseph Radford ....January 22nd, 1836
Joseph Atkinson Ransome, F.R.C.S. ...April 29th, 1836
Thomas Ransome ....January 26th, 1847
Robert Rawson ....January 21st, 1845
Rev. William Read, B.A ....January 23rd, 1824
Rev. John Gooch Robberds ....April 26th, 1811
John Robertson ....April 20th, 1827
Richard Roberts, M. Inst. C.E. ......January 18th, 1823
Samuel Robinson ....January 25th, 1822
Alan Royle....................................January 25th, 1842

Michael Satterthwaite, M.D. .. ..January 26th, 1847
Edward Schunck, Ph. D. ....January 25th, 1842
Salis Schwabe.................................April 20th, 1847
John Sharp ....October 28th, 1824
John Shuttleworth ....October 30th, 1835
Geo. S. Fereday Smith, M.A., F.G.S....Jan. 26th, 1838
Robert Smith, Ph. D. ....April 29th, 1845
Edward Stephens, M.D. ....January 24th, 1834
James Stephens ....April 20th, 1847
Robert Stuart ....January 21st, 1814
William Sturgeon ....October 29th, 1844

Rev. John James Tayler, B.A..........January 26th, 1821

	Date of Election.
John Thom	January 27th, 1846
Edmund Peel Thomson	January 21st, 1820
Robert Thorpe	November 3rd, 1815
James Aspinal Turner	April 29th, 1836
Thomas Turner, F.R.C.S	April 19th, 1821
Francis Eugene Vembergue	January 27th, 1832
Absalom Watkin	January 24th, 1823
Joseph Whitworth	January 22nd, 1832
Alexander Wightman	October 19th, 1847
Matthew A. Eason Wilkinson, M.D.	January 26th, 1841
William James Wilson, F.R.C.S	April 29th, 1814
Gilbert Winter	November 2nd, 1810
William Rayner Wood	January 22nd, 1836
Bennett Woodcroft	January 26th, 1841
George Woodhead	April 21st, 1846
Edward Woods	April 30th, 1839
Robert Worthington	April 28th, 1840
James Woolley	November 15th, 1842
Joseph St. John Yates	January 26th, 1841
James Young	October 19th, 1847

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